PROCEEDINGS

THE INSTITUTION OF CIVIL ENGINEERS

PART I
JULY 1954

ORDINARY MEETING

16 February, 1954

WILFRID PHILIP SHEPHERD-BARRON, M.C., T.D., President, in the Chair.

The Council reported that they had recently transferred to the class of

Members

Collins, John Jerome, *M.C., T.D.*
Driver, Eric William, B.Sc.(Eng.) (*London*).
Grant, Andrew Francis Joseph, B.Sc. (Eng.) (*London*).
Hale, Hugh Thomas, *T.D.*, B.Sc.(Eng.) (*London*).
Kipps, Oliver, B.Sc. (*Birmingham*).
Mander, George Charles, *M.B.E.*, B.Sc. (*Bristol*).
Moore, James Thomas, B.Sc. (*Glasgow*).
Ockleston, Allan Joshua, Ph.D. (*Bristol*), D.Sc. (Eng.) (*Witwatersrand*), B.E. (*New Zealand*).
Richardson, Leslie.
Sinclair, Thomas Stoddart.
Swift, Derek John, B.Eng. (*Sheffield*).
Unwin, Roland Buckley, B.Sc.(Eng.) (*London*).
Warnock, John, *M.C.*

and had admitted as

Graduates

Akande, Christopher Sunday Olutunde, B.Sc.(Eng.) (*London*), Stud. I.C.E.
Alexander, Raymond George, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Anderson, Alastair William, B.Sc. (*Glasgow*), Stud.I.C.E.
Anderson, William Greer, B.A., B.A.I. (*Dublin*), Stud.I.C.E.
Ashman, Arthur Brian, Stud.I.C.E.
Barrett, Arthur George, B.Sc. (*Natal*).
Barry, Trevor James, B.A., B.A.I. (*Dublin*).
Bibby, Jack Donald, Stud.I.C.E.
Bown, Bruce Osborne, Stud.I.C.E.
Boyle, Patrick, B.E. (*National*).
Bray, David Gerald, B.E. (*W. Australia*).
Bristow, Ronald George, B.Sc.(Eng.) (*London*), Stud.I.C.E.
Brown, James, B.Sc. (*Glasgow*).
Brown, Michael John Anthony.
Brown, Roger Keith, B.Sc.(Eng.) (*London*).
Browne, Michael Walter, B.Sc. (*Edinburgh*).
Burgoyne, Derek Peter, B.Eng. (*Liverpool*), Stud.I.C.E.

CAIN, JACK ANTHONY, B.Sc.(Eng.) (*London*).
CARDER, JOHN FREDERICK, B.Sc. (*Leeds*), Stud.I.C.E.
CARPENTER, ALEC CLIFFORD, B.Sc.(Eng.) (*London*) Stud.I.C.E.
CASWELL, ARTHUR HUGH, B.Sc.(Eng.) (*London*).
CHAPLIN, GEOFFREY, Stud.I.C.E.
CLARK, PETER GEOFFREY, B.A. (*Cantab.*), Stud.I.C.E.
CLEVERLEY, RAYMOND JOHN, B.Sc.(Eng.) (*London*).
CRAMP, GERALD, B.Sc. (*Northampton*), Stud.I.C.E.
CUCKSEY, IAN THOMAS, B.Sc. (*Birmingham*).
CUPITT, PETER, B.Sc. (*Birmingham*).
DAVIDSON, WILLIAM, B.Sc. (*Aberdeen*).
DAVIES, ALAN VAUGHAN.
DAVIES, CHRISTOPHER JOHN, Stud.I.C.E.
DAVIS, FREDERICK PETER, B.Sc.Tech. (*Manchester*).
DAWSON, DOUGLAS JAMES IMRIE, Stud. I.C.E.
DEVLIN, PATRICK, B.Sc. (*Belfast*).
DRAKE, JOHN, B.Sc.(Eng.) (*London*).
DUGDALE, ROGER HOUGHTON, B.Sc.(*Eng.*) (*London*).
EDMONDSON, HARRY DEAN, B.Sc.(Eng.) (*London*), Stud.I.C.E.
EDWARDS, PETER CYRIL, B.Sc.(Eng.) (*London*), Stud.I.C.E.
ELLIS, MALCOLM LEARMONTH LYALL, B.Sc. (*St Andrews*), Stud.I.C.E.
FERNER, MARTIN HAROLD, B.E. (*New Zealand*).
FORSTER, JOHN TREVOR, B.Eng. (*Liverpool*), Stud.I.C.E.
GABB, ALFRED DANIEL FREDERICK, Stud. I.C.E.
GRAY, NEIL FARQUHARSON, B.Sc. (*Durham*), Stud.I.C.E.
GREGORY, CLIFFORD GORDON, B.Sc.Tech. (*Manchester*), Stud.I.C.E.
GUNASEKERA, JUSTIN, B.Sc.(Eng.) (*London*), Stud.I.C.E.
HAMILTON, RONALD THOMAS, B.Sc. (*Aberdeen*).
HANSON, DOUGLAS, B.Sc.(Eng.) (*London*).
HARDING, EDMUND RUDGE, B.Sc.(Eng.) (*London*), Stud.I.C.E.
HARRIS, JOHN DAVID, Stud.I.C.E.
HAWKINS, PETER, B.Sc. (*Edinburgh*), Stud.I.C.E.
HINDHAUGH, GEORGE MICHAEL ATKINS, Stud.I.C.E.
HOGG. HENRY MOLLISON, B.Sc.(*Glasgow*).
HOLMAN, PETER DEREK, Stud.I.C.E.
HORN, RAYMOND WILLIAM, Stud.I.C.E.
HUFFORD, HOWARD HORACE, Stud.I.C.E.
HUGHES, COLIN GEORGE, B.E. (*Sydney*).
HUGHES, PETER EDWARD ARMSTRONG, B.Sc.(Eng.) (*London*), Stud.I.C.E.
IDLE, ROBERT ANTHONY, B.Sc. (*Durham*), Stud.I.C.E.
IGO, RAYMOND JAMES, B.Sc. (*Nottingham*).
JEE, RAYMOND, B.Sc. (Eng.) (*London*).
KANTHASAMY, NADARAJAH, B.Sc.(Eng.) (*London*), Stud.I.C.E.
KHABAZA, ALBERT MURAD, B.Sc.(Eng.) (*London*).
KING, PATRICK JOSEPH, B.E. (*National*).
LEES, DAVID GORDON, B.Eng. (*Sheffield*), Stud.I.C.E.
LESLIE, RALPH EDWIN ALAN, B.Sc.(Eng.) (*London*).
LEVY, GEOFFREY HOWDEN, B.Sc.(Eng.) (*London*).
LEVY, MUSA SASSOON, Stud.I.C.E.
LISTER, GEOFFREY EDWARD, B.Sc. (*Glasgow*).
LOBO, JULIUS BERNARD, B.Sc.(Eng.) (*London*), Stud.I.C.E.
LOVELL, ARTHUR HUGH LUSHINGTON, Stud.I.C.E.
MACDONALD, SIMON, B.Sc. (*Aberdeen*).
MCGARRY, JOHN BRIAN, B.Sc. (Wales).
MCGUFFIE, GORDON WILLIAM, B.Sc. (*Manchester*).
MCLAY, ALASTAIR JOHN, B.Sc. (*St. Andrews*), Stud.I.C.E.
MANSELL, BRIAN WILLIAM, Stud.I.C.E.
MEADE-KING, RICHARD OLIVER, B.A. (*Cantab.*).
MOORE, JOSEPH THOMPSON, Stud.I.C.E.
MORRIS, WILLIAM JAMES, B.Sc.Tech. (*Manchester*).
MORROW, VICTOR EDWARD, Stud.I.C.E.
MURPHY, JAMES SMITH, Stud.I.C.E.
NADARAJAH, VELUPPILLAI, Stud.I.C.E.
NETTLETON, KENNETH ARTHUR, B.Sc. (Eng.) (*London*).
O'CALLAGHAN, MICHAEL JOSEPH, B.E. (*National*).
OLIVER, OSWALD JOHN, B.Eng. (*Liverpool*), Stud.I.C.E.
ORR, SAMUEL, B.Sc. (*Belfast*).
PANDITARATNE, JOSEPH IVOR TUDOR DON PASCHAL, B.Sc.(Eng.) (*London*), Stud. I.C.E.
PARKER, ALAN SCOTT, B.Sc. (*Leeds*).
PARR-BURMAN, JOHN DAVID, B.Sc. (*Edinburgh*), Stud.I.C.E.
RAVEN, JOHN TREVOR, Stud.I.C.E.
REMEDIOS, ANTHONY PHILIP, B.Sc.(Eng.) (*London*), Stud.I.C.E.
RIDDELSDELL, MALCOLM ALEXANDER, Stud.I.C.E.
RITCHIE, ANTONY RICHMOND, B.Sc.(Eng.) (*London*), Stud.I.C.E.
ROBERTS, RICHARD WILLIAM, B.Sc.(Eng.) (*London*).

Ross, James Fergus. B.Sc. (*Belfast*).
Rowell, Dennis Lancaster, B.Eng. (*Liverpool*).
Shah, Sashikant Jivan, B.Sc.(Eng.) (*London*).
Sharratt, James Oliver, Stud.I.C.E.
Simmonds, Eric John, Stud.I.C.E.
Smith, Alan Andrew, B.Sc. (*Glasgow*), Stud.I.C.E.
Smith, Albert Charles, B.Sc.(Eng.) (*London*).
Smith, Peter, B.Sc. (*Leeds*).
Smith, Sydney Maxwell John.
Stevenson, William Mayne Corden, B.Sc. (*Belfast*), Stud.I.C.E.
Swinney, Henry, Stud.I.C.E.
Sylvester, Alfred Kenneth.
Tanner, Roy Galbraith, B.Eng. (*Liverpool*), Stud.I.C.E.
Tarte, Gerald Stuart, B.Sc.Tech. *Manchester*), Stud.I.C.E.
Taylor, John Paskin, B.A. (*Cantab.*).
Thomas, Royston James, Stud.I.C.E.
Tindall, Eric Francis, B.Sc.(Eng.) (*London*), Stud.I.C.E.
Townsend, John Lloyd, B.Sc. (*Birmingham*).
Waite, Richard Everard, B.Sc. (*Durham*).
Ward, Michael Fulford, B.Sc. (*Bristol*), Stud.I.C.E.
Watson, Roger David, Stud.I.C.E.
Watson, William, B.Sc. (*Glasgow*).
Welborn, Herbert Hendrick, B.Sc. Tech. (*Manchester*).
Wild, Alan Vincent, B.Sc.Tech. (*Manchester*).
Wiseman, John, B.Sc. (*Aberdeen*).

and had admitted as

Students

Aitken, Ian Bryce.
Alexander, Michael William.
Alexander, Moses James Kenneth.
Bevan, David Milton.
Brinson, Anthony George.
Bullard, David Gray.
Burnell, Anthony John.
Burt, Peter Graham.
Butler, Frederick George.
Cairns, Desmond
Canavan, Columba Anthony Paschal.
Carter, Stephen William Speakman.
Clare, Edward Lewis.
Clegg, Paul.
Constance, Clive Erle.
Cooper, Robert
Cornick, Peter Charles.
Cottam, George David Guy.
Crabb, Victor Stephen.
Crooks, Walter Herbert.
Cuthbertson, Alexander.
Dickson, Alastair Malcolm.
Domleo, Ian Stephen.
Dubourg, William David.
Durose, Bryan William.
English, Alexander William.
Ettinger, Norman Barry.
Evans, Edgar Anthony.
Fapnsworth, Peter Sayers.
Ferguson, William.
Galbraith, William James Lethem.
Gilpin, Roger Alec.
Harlock, Anthony.
Hewitt, Robert Howard.
Higher, Geoffrey Eric Gordon.
Holdsworth, Charles Douglas.
Horobin, Roy.
Howley, Michael.
Hyman, Ian.
James, Derek Charles Roy.
John, Gwion Terence.
Jones, John Kenneth.
Kent, Michael Percival.
Lambert, Brian Ross.
Lancaster, Robert Mortimer.
Lawrence, Peter John.
Leon, Victor Ralph.
Li Pai Lin.
Manners, George Robert.
Marris, Alexander.
Matier, George (*Jun.*).
Minelly, John.
Mitchell, Ronald.
Nayar, Krishnapillai Velurillai Chandrasekharan.
Newman, Joseph Sidney.
Norton, John.
Nutt, Geoffrey William.
Oosthuizen, Andries Petrus Cornelius.
Osborne, David John.
Paterson, John.
Pont, Arthur Michael Stalkartt.
Price, Edward Richard.
Ramsay, John Malcolm.
Reynolds, Michael.
Robb, Andrew Dewar.
Roberts, James Arthur Sturgess.
Scott, David Ward.
Sekhon, Manjit Singh.
Skinner, Ronald Alister.
Smith, Alan Rufus.

SNAGGS, KENNETH BERTRAM.
STANLEY, BRIAN WILLIAM.
TANTON, MALCOLM STANLEY.
TOBIN, NICHOLAS KEVIN.
UPWARD, GORDON HAROLD.
VYVYAN, BERNARD JEREMY.
WAILES, TIMOTHY JOHN.
WEBB, JOHN HENRY.
WILLIAMS, DAVID MYDDLETON.
WOODWARD, JOHN FRANK.

The following Paper was presented for discussion and, on the motion of the President, the thanks of the Institution were accorded to the Author.

Paper No. 5975

"The History and Construction of the Foundations of the Asia Insurance Building, Singapore"

by

William Joseph Robert Nowson, B.Sc.(Eng.), A.M.I.C.E.

SYNOPSIS

This Paper describes essentially the underpinning of partially sunk reinforced-concrete cylinders by means of a precast concrete segmental lining. The early history of the foundations is related fairly comprehensively and reference is made to the main points in the design. The partial sinking of the cylinders, of which a brief account is given, was carried out by another contractor.

The cylinders form the main part of the foundations for the 18-storey steel-framed Asia Insurance Building to be erected in Singapore. The site is located over an old beach reclaimed within the past 70 to 80 years. The beach formation is 10 to 14 feet thick. Overlying it is 15 to 18 feet of fill and below it is decomposed shale and sandstone. Four borings, sunk at various points on the site, came to refusal at depths ranging from 30 to 42 feet. Firm sandstone chippings were obtained in each case. The consistency of these results suggested the existence of a firm rock stratum. Lack of suitable drilling equipment in Malaya at that time prevented the rock from being proved at depth.

On the basis of this information, cylinder foundations were selected to be sunk to rock level. The cylinders were designed for a bearing pressure of 10 tons per square foot exclusive of their own weight.

During the sinking of the cylinders the soil analyses were confirmed, except that the sandstone at depth proved to be core boulders of sandstone. The situation was considerably aggravated by the inrush of soil during the sinking of the cylinders through the beach formation, causing considerable trouble and delay. The surrounding ground showed a series of cracks and, close to one side of the building line, the pavement had sunk from 2 to 3 feet.

The subsidence is attributed to the disregard, on the part of the previous contractor, of the specifications relating to the method of sinking the cylinders. Control of the water table was erratic and excavation inside the cylinders was allowed to proceed too far ahead of the cutting edge.

To avoid further risk of loss of ground, sinking of the cylinders was stopped. The cylinders were carried to their final level (45 to 55 feet below the road level) by underpinning them with a precast concrete segmental lining. The bearing pressure was reduced to 3·5 tons per square foot by "belling out" the bases. All cylinders were back-grouted, and also each ring of the lining as it was assembled. In certain cases underpinning through the beach formation was carried out in compressed air.

After sealing the bottoms of the shafts and encasing the segmental rings in a secondary lining, the tops of the cylinders were trimmed to a common level and a 4-foot-thick reinforced-concrete raft was cast over them. Into the raft were grouted the holding-down bolts and base plates for the stanchions of the steel superstructure.

The Paper also gives a detailed account of the soil surveys. It describes the manufacture of the precast concrete segmental lining and gives brief notes on the plant and tools used during the execution of the work, including general progress.

Introduction

The proposed Asia Insurance Building is an 18-storey steel-framed building, approximately 242 feet high, to be built for the Asia Insurance Company, Ltd, in Singapore. *Fig. 1* is reproduced from an artist's impression of the completed structure.

This Paper describes, mainly from the Contractor's point of view, the work carried out on the foundations by Messrs Gammon (Malaya) Ltd, which essentially involved the underpinning of partially sunk reinforced-concrete cylinders with a prefabricated lining. Only brief reference is made to the sinking of the cylinders to their existing level since that work had previously been carried out by another contractor and the Author was unable to obtain the necessary information.

In order to appreciate the reason for underpinning the cylinders, it is necessary to review fairly comprehensively the history of the foundations from their inception, and also to refer to some of the more salient points in the design.

Part I.—History of the Foundations

General Description

The site of the Asia Building is at the junction of Raffles Quay and Finlayson Green (see *Fig. 2*). On one side of it is Finlayson House, which is in the process of construction and replaces the old Clouet building, and on the other side is the five-storey K.P.M. (Koninklijke Paketvaart Maatschappij N.V.) building which was completed in 1930. The Clouet building, which was only one storey high, was still in existence when the first soil investigation was made early in 1949. The building was not demolished until the end of 1950.

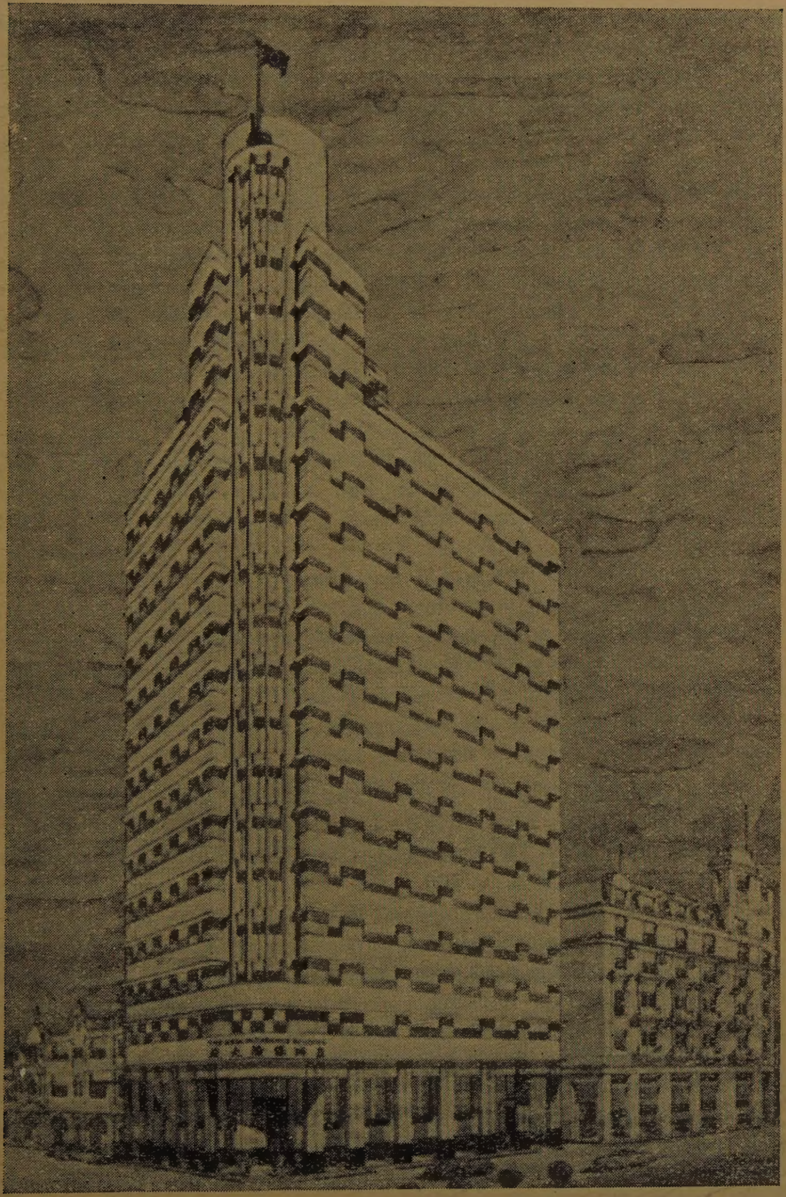
The total estimated weight of the Asia Building at stanchion-base-plate level (R.L. + 103·15) is 18,350 tons. The floor area at this level is 9,720 square feet, giving an average intensity of loading of 1·89 ton per square foot.

All levels are based on the Municipal Datum which is R.L. + 100·00 for Mean Sea Level. The Admiralty value for this level is + 5·57 feet based on Low Water Indian Spring Tide, which is zero.

First Soil Investigation

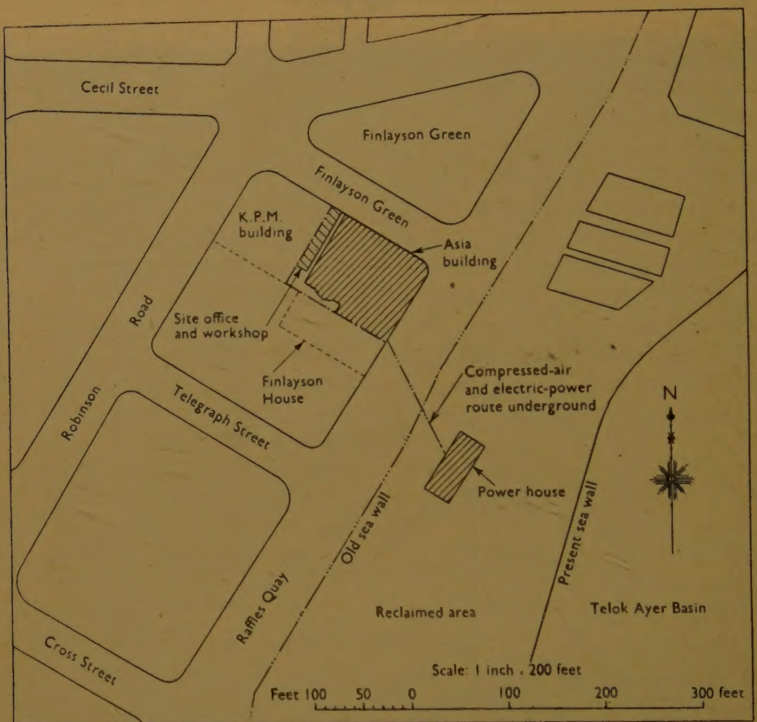
The site of the Asia Building is located near an old sea wall, a short distance from the Telok Ayer Basin, and lies on land reclaimed during the past 70 to 80 years (see *Fig. 2*).

Fig. 1



ARTIST'S IMPRESSION OF THE FINISHED BUILDING

Fig. 2



SITE PLAN

The original building on this site was founded on concrete footings 18 to 20 inches thick, supported on Bakau piles $6\frac{1}{2}$ to $7\frac{1}{2}$ feet long by 4 to 6 inches diameter. The levels of the tops of the footings ranged from about R.L. + 104 to R.L. + 106. The yard level of the old building was at R.L. + 109·6 and the pavement at R.L. + 109·9.

The Municipal Survey Department possessed no records of the existing building and no reliable information could be obtained on the piling work for the adjacent K.P.M. building. According to plans deposited with the Municipal Architect's Department the K.P.M. building rests on concrete piles 40 to 45 feet long, but the Serang (Indian foreman) who was engaged on the building reported that piles of that length could not be driven. Apparently the piles were only 20 feet long, from which it was estimated that the toe was at R.L. + 80.

The water table was measured on different occasions and was found to vary with the tide and/or rainfall through the range from R.L. +104·9 to R.L. + 102·0.

In March 1949, the subsoil was explored by means of a penetrometer and sample-taking equipment. Developed by the Royal Swedish Geotechnical Institute, the penetrometer is an instrument for determining the relative consistency of clay. It consists of a steel rod with an auger-shaped point at the bottom and handle-bars at the top. In soft ground, rotation will normally cause it to sink under its own weight, but in firmer soil it is necessary to load it by increments up to 100 kilograms (220 lb.). By recording the penetration of the instrument for a given number of half or full turns, an indication of the varying consistency of the ground may be obtained. The instrument finally comes to refusal either by striking rock or by meeting a layer of soil whose resistance it cannot overcome.

Three borings were made with the penetrometer at points 1, 2, and 3 shown on the key plan in Fig. 3, Plate 1. The subsoil was too irregular and resistant to yield much information to the penetrometer. In bore No. 1 a thin layer of great resistance was met at R.L. + 92·0 above the softer layer. Similar layers were met in bores Nos 2 and 3, both at R.L. + 95·0. All penetration tests came to refusal at rather shallow depths : R.L. + 89·0 for bore No. 1 ; R.L. + 92·0 for bore No. 2 ; and R.L. + 91·0 for bore No. 3. Penetration tests were carried out to a greater depth in bore No. 1 after sinking some casings, and results indicated that the subsoil at R.L. + 75·0 to R.L. + 71·5 is no more resistant than that at higher levels, say R.L. + 95·0.

Casings were sunk at points 1, 2, 3, and 4 and numerous soil samples, a few of which were undisturbed, were obtained. The location of the borings, and the types and depths of the strata encountered, are shown in Fig. 3, Plate 1. The soil samples in bore No. 1 were rather widely spaced, which accounts for the blank intervals in the diagram. All four borings came to refusal at reduced levels + 68, + 80, + 72, and + 79 respectively. In all boreholes a heavy chisel was used at depth and in each case it rebounded. Chippings of firm sandstone were obtained.

From the samples obtained it was possible to classify the subsoil into four distinct strata. Measuring depths downwards from R.L. + 110·0 they are :—

(*a*) 15 to 18 feet of fill ;
(*b*) 10 to 14 feet of old beach formation ;
(*c*) Varying depths (0 — 10 feet) of decomposed shale and sandstone ;
(*d*) Sandstone.

The fill is decomposed shale with fragments of sandstone, quartz veins, etc., that is, the detritus typical of a hill cut in the southern part of Singapore. The thin layer of great resistance to the penetrometer, mentioned above, is the surface of the old beach. The beach formation contains much old coral in the usual base of mud streaked with sand. The coral is quite porous and rather soft, and probably scattered in isolated colonies. There was no evidence of a compact and dense coral reef.

The decomposed shale is a very stiff multi-coloured clay with fragments of decayed stone. It is predominantly red with streaks of yellow, orange, and white. An undisturbed sample obtained in bore No. 1 at R.L. + 75 had a density of 133 lb. per cubic foot, which is high and characteristic of shale decomposed in situ. The shear strength as determined by the cone test was 1,230 lb. per square foot.

As mentioned above, a heavy chisel was used at the bottom of each borehole revealing the presence of firm sandstone in each case. These results, coupled with the fact that the sandstone occurred at relatively uniform depth, appeared to confirm that it was not a question of isolated boulders, but a solid stratum of rock. It was unfortunate that lack of suitable drilling equipment in Malaya at that time prevented the rock from being proved to a depth of 20 to 30 feet.

Preliminary Design Considerations

The results of the soil survey described above gave rise to the consideration of two types of foundations—piled or cylinder—which were to extend to the presumed sandstone bottom. It was anticipated that the pile driving would be very hard, necessitating the use of strong cast-iron shoes with a very acute angle. The piles, if successfully driven, would be able to support very heavy loads. The sinking of the cylinders might present difficulties in water keeping, but by careful control of the water table this problem could be overcome. The great advantage offered by cylinders over piles would be in the proper inspection of the presumed sandstone face. Also, by enlarging the bases of the cylinders after reaching a suitable depth, the bearing pressure at foundation level could be materially reduced to suit existing conditions. It was anticipated that cylinders might prove more economical than piles. Whatever the solution, it was realized that it was essential that the foundations be carried to the presumed sandstone as the decomposed shale overlying it is compressible, in spite of its high density. There was danger in drawing conclusions from the success of the K.P.M. building next door which was only five storeys high (equivalent to six storeys of the Asia building).

Type and Details of Foundation Adopted

The type of foundation eventually selected comprised a reinforced-concrete raft resting on cylinders to be carried to the presumed sandstone surface. The cylinders were designed for a bearing pressure of 10 tons per square foot, exclusive of their own weight. The object of introducing the raft was to transfer the point loads from two or more stanchions to one cylinder and thus restrict the number of cylinders to the minimum.

The original scheme of keeping the total number of cylinders to the absolute minimum (nineteen altogether) was abandoned, partly because the

transfer of stanchion loads was complicated and irrational, and partly because it entailed projecting the cylinders under the roads. A number of amendments were also made to the stanchion loads supplied by the designers of the steel superstructure. The number of cylinders incorporated in the final design was increased to twenty-eight, resulting in a variation of bearing pressure from 10·63 to 5·45 tons per square foot. Details of the raft showing the location of the cylinders and columns are given in Figs 4, Plate 1

The cylinders were standardized into four different types. The number and sizes were as follows :—

Type	No. of cylinders	External diameter feet	inches
A	5	15	0
B	3	13	6
C	2	12	0
E	18	8	0

The cylinders (see Figs 5, Plate 1) are in reinforced concrete and the thickness of the walls ranges from 12 inches to 2 feet 3 inches according to the type. The concrete mix for the cylinders was designed for the minimum content of 510 lb. of cement per cubic yard of finished concrete. All reinforcement was $\frac{5}{8}$-inch diameter.

In September 1949, tenders were invited for the construction of the foundations as described above, and a contractor was appointed by the owners. Work started in January 1950.

Sinking of Cylinders

During the execution of the work the results of the soil analyses were confirmed, but the sandstone at depth turned out to be core boulders or seams of softer sandstone up to 2 or 3 feet in thickness. This is the weathered triassic formation of shale and sandstone found as a rule in this part of the Island of Singapore. This formation is generally weathered to depths ranging from a few feet to 100 feet or more.

The decomposed shale and sandstone formation underlying the beach formation was confirmed.

The beach formation conformed with the results of the soil survey, except that a number of granite boulders were found in it, presumably discarded by ships which were carrying them as ballast in olden days. Regarding the coral, there were, in fact, indications of one or more continuous coral banks, but these were very porous with big cavities.

The situation was considerably aggravated by the inrush of soil during the sinking of the cylinders through the beach formation, causing considerable trouble and delay.

The ground in the vicinity of the K.P.M. building was gradually subsiding. Examination of the site on the 25th June, 1951 showed that a strip of

concrete 2 feet wide by 3 feet deep, part of the raft foundation of the old building, was adhering to the K.P.M. building. The Bakau piles which originally supported this section of the old raft were visible, but they had sunk so that their tops were now from 6 to 12 inches below the underside of the concrete.

On the Finlayson Green side, the road showed a series of cracks in the asphalt parallel to the building line and extending a distance of 15 to 20 feet to the centre of the road. At the building line the pavement had sunk between 2 and 3 feet throughout the length of the frontage.

There was no sign of cracking, and very little subsidence, on the Raffles Quay side. It was no longer possible to observe signs of settlement on the north-west side where the old building had been pulled down and the site levelled.

Although detailed provisions were made to carry out the sinking of the cylinders from ground level, the site had been excavated to a depth of as much as 14 feet in places. The timbering of the sides of the excavation was very precarious and in many places the ground had collapsed and had not been reinstated.

Inspection of Cylinders

In June 1951, five cylinders were inspected by a senior engineer of Messrs Soil Mechanics Ltd, and the following observations made :—

(1) *Cylinder* A4—*25th and 28th June, 1951*

Difficulty was experienced in pumping out the water and cleaning the bottom of the excavation. During this process there were slips of mud and shells originating from the beach formation, the bottom of which was at R.L. + 85 at this particular location. The cutting edge, which was at R.L. + 67, was resting on large boulders of hard red and white sandstone, some of which appeared to have been dragged down from the top of the stratum (a distance of up to 15 feet), and some of which were in situ. *Fig. 6* (facing p. 418) shows conditions at the bottom of this cylinder. The in-situ rocks appeared to dip steeply to the south-west or west, but the structure was very confused. The bottom of the cylinder showed much sandstone set in clay, which was covered by fine to medium sand, presumably washed over by the inflowing water. A pump was kept running continuously. At one point several Bakau piles could be observed which had been dragged down under the cutting edge. These had presumably slipped under the cylinder as a result of a local loss of ground at a higher level. At this point, and also where the large boulders had been dragged down by the cutting edge, runs of ground from the

soft beach formation had occurred. That the subsidence of the ground had not been even greater was probably attributable to the choking effect of the coral. An undisturbed sample, taken from 12 inches below the bottom of the excavation, revealed a stiff red, green, and white mottled clay with inclusions of yellow sandstone. The sandstone inclusions crumbled easily between the fingers. At the bottom of the sample tube the sample parted on a steep dip (which seemed to confirm earlier observations) and showed an easily crumbled soft red sandstone.

(2) *Cylinders E2 and E5—27th and 28th June, 1951, respectively*
These two cylinders had been excavated to R.L. + 70 and R.L. + 74 respectively. In both cases the bottom of the excavation consisted almost entirely of clay with small pieces of sandstone. Boulders were visible on the sides of the excavation below the cutting edge. Both cylinders showed evidence of black mud from the beach formation.

(3) *Cylinders B2 and E11—26th June, 1951*
The cutting edges of these two cylinders were at R.L. + 83 and R.L. + 88 respectively, both still in the beach formation. This consisted of very soft black mud with spongy corals, and also hard dense corals. The bottoms of the cylinders were covered in fine shell fragments which, presumably, were washed in by the large flow of water.

At the time the cylinders were inspected, certain ground tests were being carried out on the site of the proposed new Finlayson House, along a line passing roughly through cylinders E1 to E5. The results of the tests were kindly made available and this data, coupled with excavation records for cylinders E1 to E5, suggested that the surface of the hard clay slopes towards the south. There is, presumably, a general slope towards the old deep channel which, it is understood, was discovered during the construction of the piers in front of the Telok Ayer Basin.

Allowable Safe Bearing Pressure

In order to determine the safe bearing pressure under the cylinders, three aspects were considered :—

(*a*) Breaking into the foundations.
(*b*) Settlement.
(*c*) The possibility of the whole formation slipping downhill.

With regard to (*a*), the allowable soil pressure could most satisfactorily be determined in a triaxial compression apparatus or a shear box, neither of which was available in Singapore at the time.

Settlement of a structure founded on clay is unavoidable. The degree of settlement is a function of the properties and depth of the clay. In this case the coefficient of consolidation was expected to be small, but the net thickness of clay (after deducting any rock strata) down to a depth of 100 feet was unknown. Furthermore, information was required as to whether there existed different thicknesses of clay in different parts of the site. This would cause differential settlement which might be serious.

It was thought that the possibility of sliding downhill would be adequately guarded against by sinking the foundations well into the clay, that is, at R.L. + 65, unless a soft clay seam existed in the seat of an old slip below the foundations.

Further information was required of the subsoil at greater depth before settlement and slip possibilities could be checked.

Second Soil Investigation by Diamond Drilling

By this time, drilling equipment had become available in Singapore and four more bores were sunk down to R.L. + 15 approximately in cylinders A1, A4, B2, and E5. This work was carried out between September and December 1951. The drilling equipment used was a diamond drill consisting of a tube with an outer diameter of $1\frac{1}{8}$ inch and an inner diameter of $\frac{7}{8}$ inch. The drill water passes through the wall of the tube and is discharged through small holes 1 inch above the cutting edge. The boring records are shown graphically in simplified form in Fig. 3, Plate 1.

It had been hoped that it would be possible to drill through the sandstone boulders with the diamond drill and then to sample the clay by pushing into it a thin-walled steel tube of $\frac{3}{4}$ inch external diameter. This was found impracticable since it was not possible to recognize when the drill was in sandstone and when it was in clay. The samples sent to the laboratory for testing were, therefore, all cores taken by the diamond drill and none of them could strictly be described as "undisturbed." Some clay samples had been considerably softened by drilling water, others were in reasonable condition. The samples extracted did not form a continuous core. This accounts for the blank intervals in the last four boring records shown in Fig. 3, Plate 1. The missing portions of the cores probably consisted mainly of a weak decomposed sandstone or decomposed shale.

A total of ten undisturbed samples of clay from the bottoms of cylinders A1, B2, E2, E4, E5, and E6 were collected from depths ranging from R.L. + 76 to R.L. + 64. The samples were sent to England in sealed containers for testing.

Test Results of Second Soil Investigation

From the diamond-drill cores several samples of clay, which appeared to have been taken without using drilling water and which were in good

condition, were tested to determine index properties, moisture content, and shear strength. Similar tests were made on specimens cut from the undisturbed samples. Consolidation tests were carried out on two specimens from the diamond-drill cores and on six specimens from the undisturbed samples. Two of the samples tested reached the laboratory in a very softened condition and the tests on these were ignored. Another two samples which gave the next lowest shear strengths, 2,760 and 1,640 lb. per square foot, were taken from cylinders E2 and E5 at a depth between 2 and 3 feet below the bottom of the excavation. The cylinders had been standing full of water for some weeks, and swelling and consequent softening had therefore probably occurred. Apart from these results, sixteen other tests gave shear strengths in excess of 3,000 lb. per square foot. There was a wide variation in shear strength.

Purely from consideration of shear failure, the estimated safe working value was taken as 3,000 lb. per square foot, which, with a factor of safety against failure of 3, would give a net safe bearing pressure of 3 tons per square foot. To this figure the weight of overburden above the bottom of the foundation was added. The ground level was taken as R.L. + 108 and the water table was assumed at R.L. + 102. The different thicknesses and densities of strata were assumed as follows :—

Stratum	Reduced levels	Density
Fill	+ 108 to + 93	100 lb. per cubic foot
Beach formation	+ 93 to + 80	115 lb. per cubic foot
Shale	+ 80 to + 65	130 lb. per cubic foot

Weight of overburden from R.L. + 108 to R.L. + 65 :—

R.L. + 108 to R.L. + 102 : $6 \times 100 = 600$ lb. per sq. ft.
R.L. + 102 to R.L. + 93 : $9(100 - 62{\cdot}4) = 338$ „ „
R.L. + 93 to R.L. + 80 : $13(115 - 62{\cdot}4) = 680$ „ „
R.L. + 80 to R.L. + 65 : $15(130 - 62{\cdot}4) = 1{,}010$ „ „

Total weight of overburden . . . $= 2{,}628$ „ „ $= 1{\cdot}2$ tons per sq. ft.

Permissible pressure without overburden . . . $= 3{\cdot}0$ tons per sq. ft.

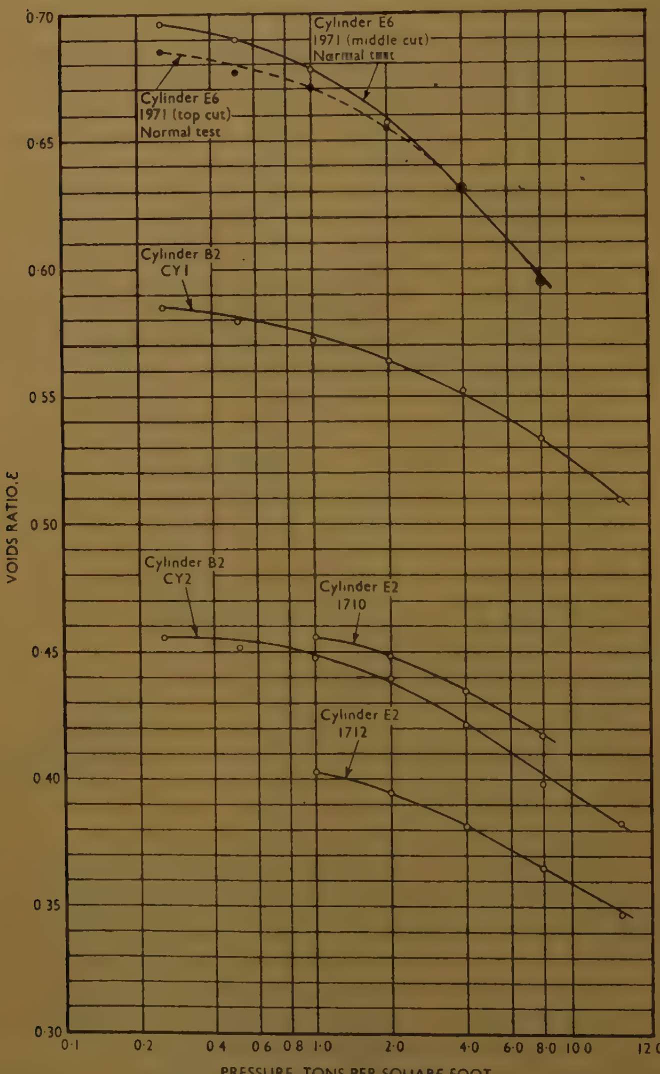
Therefore, safe bearing pressure at R.L. + 65 . . . $= 4{\cdot}2$ tons per sq. ft.

Pressure/voids-ratio curves determined from consolidation tests carried out on a number of undisturbed clay samples are given in *Fig. 7*. The curves are similar for samples 1,710, 1,712, Cy.1, and Cy.2, though there are considerable differences in the consolidation coefficient which ranges from 0·0845 to 0·3985 square centimetres per minute. For sample 1,971, the change in voids ratio for a given change in pressure is twice the corresponding change in voids ratio for the other samples.

In order to determine the amount of settlement, it was necessary to know the proportion of clay to sandstone to a depth of about 100 feet below the

foundations. The results of the diamond-drill borings were inconclusive on this point since less than 50 per cent of each individual core was recovered. Of the core material recovered, however, approximately 50 per cent was clay and the remainder sandstone, and this proportion was adopted in

Fig. 7



P — ε CURVES

Fig. 6

Cutting Edge of Cylinder A4 at R.L. + 67, showing Sandstone Boulders in Decomposed Shale

Fig. 9

Typical Trapezoidal Steel Mould (Type G) with One Side removed, showing Split Cores

Fig. 11

General View of Site from Roof of K.P.M. Building. Timber Tracks for Crawler Cranes can be seen in the Foreground (4 July, 1952)

making settlement estimates. It was also assumed that the clay was evenly distributed over the 100 feet depth.

Settlement calculations were based on a preliminary foundation design similar to the final one adopted, except that the soil stresses in the former case were slightly more severe. Two conditions of load distribution in the subsoil were assumed and compression indices determined from the pressure/voids-ratio curves given in *Fig. 7*. Calculations showed that for these two cases the differential settlements were 1 and 1·9 inch. The actual settlement was expected to fall within these limits and probably nearer the lower limit. Owing to irregular conditions existing it was not possible to predict the time in which this settlement would occur.

Reconsideration of Design

The absence of a firm rock stratum to support the cylinders as originally designed necessitated a reduction of their bearing pressure. This could be achieved either by sinking additional cylinders or " belling out " the bottom of the existing ones.

Altogether, twenty-eight cylinders were incorporated in the design of the foundations. It was not considered practicable to increase this number for a variety of reasons. The site was already congested by the proximity of the existing cylinders and the lack of space around it. Any additional cylinders would have seriously hampered progress, for work could progress only on a limited number at a time. Furthermore, about 50 per cent of the cylinders had already reached or passed the bottom of the beach formation and so far as those were concerned the worst part of the sinking operation had been overcome. The introduction of any additional cylinders would have increased many-fold the present problem of carrying the remaining ones through the beach formation.

Solution Adopted

The alternative solution was to " bell out " the cylinders at the base and this arrangement was adopted. Re-design of the foundations commenced shortly after their inspection in June 1951 and a tentative bearing pressure of $3\frac{1}{2}$ tons per square foot at R.L. + 65 was adopted. This figure was subject to revision pending the results of the tests on the soil samples. It is regrettable that, owing to circumstances beyond control, these results did not become available until more than a year later. By that time the underpinning had progressed beyond the point where it was considered economical to take advantage of the increased bearing pressure. When designing the cylinders it was assumed that they would fill with water and this additional weight, together with that of the raft and the submerged cylinders themselves, was taken into consideration.

To avoid further risk of loss of ground from the beach formation, it was decided to carry those cylinders which had not yet been started, or had not yet reached the decomposed shale below the beach formation, through this formation in compressed air by underpinning with a precast concrete lining consisting of segmental rings. Cylinders already in the decomposed shale, and others as they penetrated into this formation, were to be extended by underpinning as described above but in the open. Before any further excavation was resumed, all existing cylinders were to be back-grouted, as also was each ring of the segmental lining as it was assembled. When the shafts reached R.L. + 65 a reinforced-concrete slab 2 feet thick was to be laid at the bottom and the internal face of the segmental rings encased in a secondary reinforced-concrete lining. All cylinders projecting above the underside level of the raft were to be cut to that level and the raft cast over them.

Part 2.—Construction of Foundations

Precast Concrete Segmental Rings for Underpinning Cylinders

General Description and Factors controlling Design of Segmental Rings

Details of the precast concrete segmental rings or lining used for underpinning the cylinders are given in Figs 8, Plate 2. In principle they are similar to linings used in tunnel construction. The segments, 18 inches deep, are connected together by bolts through their longitudinal flanges to form rings. Bolts through the circumferential flanges connect ring to ring.

The main factors controlling the design of the segments were :—

(1) The segments had to be sufficiently light for lifting into position by not more than three or four men. The heaviest segments weighed 450 lb.

(2) The dimensions had to be such as to permit them to pass through the air locks.

(3) The segments had to be sufficiently robust to withstand rough handling. The most critical sections were the longitudinal and transverse flanges, the minimum thicknesses of which were 1 and $1\frac{1}{2}$ inch respectively. These flanges were a little on the light side and a minimum thickness of $1\frac{3}{4}$ inch would have probably proved more satisfactory.

(4) The rings had to be of sufficient strength to withstand the maximum earth pressure likely to be developed during underpinning operations.

In determining the circumferential length of each segment $\frac{1}{4}$ inch has been deducted to allow for inaccuracies in alignment and to facilitate assembly.

Segments were designed for underpinning each of the four types of cylinders used. The segments for each type of cylinder are characterized by the angle α which they subtend at the centre of the ring.

In the original design the rings were true circles. Since that meant fabricating curved moulds which would prove intricate and expensive the rings were given a polygonal outline.

Another modification was in connexion with the tapered washers for the bolts. These originally were to be cast in concrete integrally with the segment, but since it was anticipated that this arrangement would introduce difficulties in the fabrication and stripping of the moulds they were omitted. Separate cast-iron bevelled washers were supplied to suit individual types of segments. The disadvantage of this arrangement was the high cost of the washers and the confusion caused during assembly owing to the four different types of bevel. The minimum thickness of the cast-iron washers was $\frac{1}{4}$ inch and the internal and external diameter were $1\frac{1}{8}$ inch and 2 inches respectively.

Each segment, except the keys, was fitted with one $1\frac{1}{2}$-inch grouting pipe, 3 inches long and tapped internally.

To facilitate reference, the different types of segments were classified into three main categories according to the shape of their longitudinal flanges. See sections AA, BB, and CC in Figs 8, Plate 2.

Rectangular segments.—These segments were used in the cylindrical section of the shafts underpinning the cylinders.

Trapezoidal segments.—These segments were used to form the bellmouth section of the shafts. The bottom vertical bolt holes are staggered 6 inches radially outwards relative to the top ones, so that the diameter of each successive ring is greater than the one above it by 1 foot.

Parallelogrammic segments.—These segments are a variation of the trapezoidal segments but perform exactly the same function. They were designed during underpinning operations with a view to reducing the volume of excavation. Unfortunately at that stage most of the moulds for the segments had already been fabricated and it was possible to apply this modification to segments for cylinders types B and C only. This change in section entailed only minor alterations to the position of the horizontal bolt holes. The vertical bolt holes remained unchanged.

Each ring comprises a number of "ordinary" segments (the actual number depending on the angle α), two "special" segments, and a key. The "special" segments are those adjacent to the key, and are similar to

the "ordinary" segments except that the circumferential length has been reduced by an amount equal to half the width of the key.

To be able to differentiate between the different types of rings on the site without having reference to the diameter and the angle α, each ring was allocated a letter of the alphabet. This system was found to work very satisfactorily.

Moulds for Segments

A certain amount of experimental work was carried out on steel and wooden moulds. Steel moulds proved by far the most satisfactory, particularly in those cases where continual re-use was necessary. A typical steel mould with a side removed is shown in *Fig. 9*. The moulds were designed so that the segments were cast convex side upwards. Mild-steel plate, $\frac{1}{8}$-inch thick and $1\frac{1}{2}$-inch-by-$1\frac{1}{2}$-inch-by-$\frac{3}{16}$-inch angle-iron were the main materials used in the fabrication of the moulds. The two ties securing the two longer sides of the moulds were introduced to prevent the latter from distorting during consolidation of the concrete. All four sides of the moulds were removable.

In most cases each core was fabricated as a single unit with a pair of angles on the inside to facilitate extraction. All parts were held together by spot welding.

In certain types of moulds the core was wider at the closed end (measured circumferentially relative to a ring of segments) than at the open end, making extraction in the normal manner impossible. It was necessary to split these cores diagonally as shown in *Fig. 9*, facing p. 419. These two halves were bolted together.

In some of the first moulds the cores were located by means of two $\frac{7}{8}$-inch-diameter bolts on each side of the mould. The bolts, which were screwed into the cores, passed through a short length of pipe, $1\frac{1}{4}$-inch external diameter, located inside the mould. The position of the bolts coincided with that of the bolt holes in the segment. These short lengths of pipe were withdrawn from the segments by means of an extractor a few hours after stripping the moulds. In the later mould designs this arrangement was simplified and the bolts were replaced by plain lengths of $1\frac{1}{4}$-inch-external-diameter pipe passing right through the sides of the mould and core. Positive location of the cores, particularly in the case of the steel moulds, was obtained by means of small lugs screwed on the bottom of the moulds, which fitted into small recesses cut out of the edges of the cores. The grouting pipes were bolted to the cores.

The only serious criticism that could be levelled against the design of these moulds was in connexion with the extraction of the cores. These very often proved difficult to pull out in spite of a large taper; the difficulty was attributable to minor distortions in the metal as a result of welding.

Apart from careful cleaning and oiling after each casting operation the steel moulds required very little maintenance.

Experiments carried out on wooden moulds showed that they were satisfactory, but their life was limited to casting twenty to thirty segments, after which the timber soon deteriorated, necessitating frequent repairs. Wooden cores proved unsuitable, many of them splitting during extraction. Eventually it became necessary to fit all wooden moulds with steel cores. Balau timber, 2 inches thick, was used for the fabrication of the moulds. The inside faces were lined with $\frac{1}{8}$-inch "Pluto" asbestos facing-board.

One advantage wooden moulds possessed over steel ones was the speed with which the sides could be stripped. This was accomplished by the removal of only four wedges.

Manufacture of Segments

The main reinforcement in the segments consisted of $\frac{3}{8}$-inch-diameter bars disposed as shown in Figs 8, Plate 2. Stirrups were $\frac{1}{4}$-inch diameter at 4-inch centres, except those in the longitudinal flanges and ribs which were $\frac{3}{8}$-inch diameter. The reinforcement was tied with 18-gauge galvanized iron wire. The cages produced were quite rigid.

The specification defined the proportion of cement as 620 lb. per cubic yard of finished concrete. The aggregates used consisted of $\frac{3}{8}$-inch to $\frac{1}{8}$-inch crushed granite, and sand $\frac{1}{8}$-inch down. The moulds were stripped 24 hours after casting and the segments were matured for a period of 18 days. During the first 7 days the segments were matured by keeping them covered with gunny sacks and constantly spraying them with water.

Although the specification recommended the use of "shock" or "vibrating" tables for consolidating the concrete this equipment was not available locally and external vibrators were used instead quite successfully.

Plant and Concreting Arrangements

The concrete, which was mixed in a 10/7-cubic-foot-capacity revolving-drum mixer, was fed by hand into the moulds. A small compressor delivering air at a pressure of 100 lb. per square inch was used for operating the pneumatic vibrators. The concrete was distributed to the various moulds by means of a decauville wagon. A casting yard was not available and an open shed, 100 feet by 45 feet with a 3-inch concrete floor, was constructed.

Labour and General Progress

Chinese labour was employed for the manufacture of the segments. Twelve to fourteen men and women were employed daily, consisting of one kepala or foreman, one compressor driver, two or three bar benders, two male labourers, and six or seven female labourers.

In all, there were fifty-two moulds of thirty-two different types. Twenty-nine of these moulds were of steel and the remainder of wood. Wooden moulds were used only in those cases where a limited number (up to a maximum of thirty-six) of segments was required.

Apart from a few national holidays, the labour force worked 7 days a week and averaged about 9 hours work each day. A total of 3,614 segments, equivalent to 341 rings, were cast over a period of 5½ months giving an average of twenty-two segments per day or just over two rings per day. The maximum output reached was forty-one segments per day, and for a considerable period of time an average of twenty-six segments per day was maintained.

Cost of Segmental Rings

The segmental rings were manufactured by Messrs Gammon (Malaya) Ltd for the lump sum value of $130,000 (Straits) which included delivery.

Underpinning of Cylinders

Starting and Completion Date of Contract

Possession of the site was taken in February 1952, and the underpinning and reinforced-concrete raft were completed by the following February. The last base plate for the steel superstructure was grouted a month later, thus completing the foundations in about 14 months.

Site Lay-out

The site of the Asia Building is located in one of the busiest and most congested areas of Singapore. Lack of working space proved a great hindrance throughout the contract. Permission to obtain a site on Finlayson Green was rejected by the local authorities and eventually an area measuring 90 feet by 65 feet was secured on Crown Land in Raffles Quay almost opposite the Asia Building site (see *Fig. 2*, p. 410). It was here that the power house was located. The office and mechanical repair shop were situated in the 15-foot lane between the Asia Building site and the K.P.M. building.

One of the first operations on taking over the site was to erect the temporary power house for housing the high- and low-pressure compressors, the stand-by generators, and the air-conditioning plant. This building which was 70 feet by 30 feet, was a timber-framed structure covered with corrugated galvanized iron sheeting.

General Programme and Progress

Although the specifications required that all cylinders which had not passed through the beach formation be underpinned in compressed air, it was agreed during the early stages of the work that the final decision

as to whether this course be strictly adhered to would depend on the conditions prevailing in individual cylinders. Underpinning in the open would progress so long as there was no risk of further subsidence of the ground and the flow of water was not excessive.

Underpinning operations were divided into three main stages, involving three groups of cylinders. There was no clear line of demarcation between the different stages but essentially they were as shown in Table 1.

TABLE 1.

Stage	Period	Cylinder group	No. of cylinders
1.	March/July	E1 to E9 inclusive A1 to A3 inclusive	12
2.	July/October	B1, C1, C2, E10, E11, E12*, E15*, E16, E17, E18	10
3.	October/December	A4, A5†, B2, B3, E13†, E14†	6
		Total No. of cylinders	28

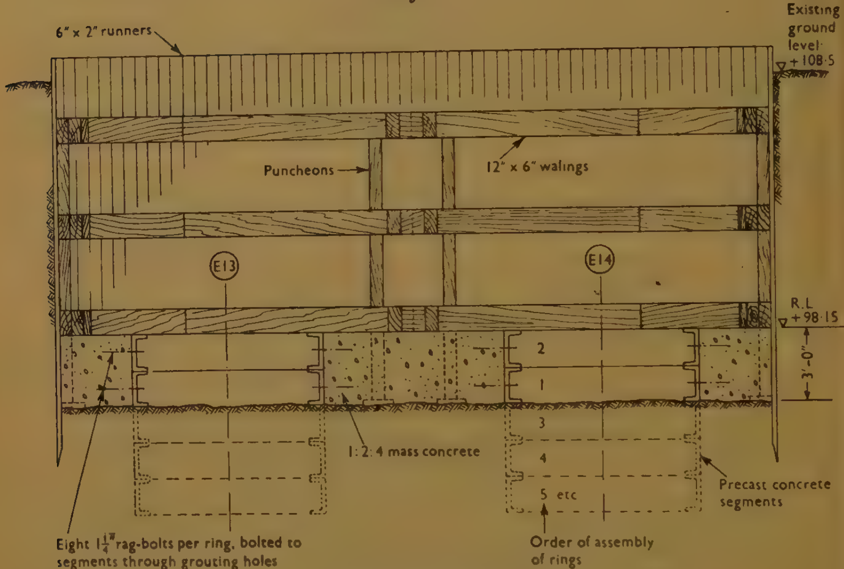
* Underpinned in compressed air.
† These shafts were sunk by the underpinning methods

Stage 1.—In this group all cylinders were through the beach formation except A1. All were comparatively dry and it was possible to underpin them in the open to foundation level without difficulty.

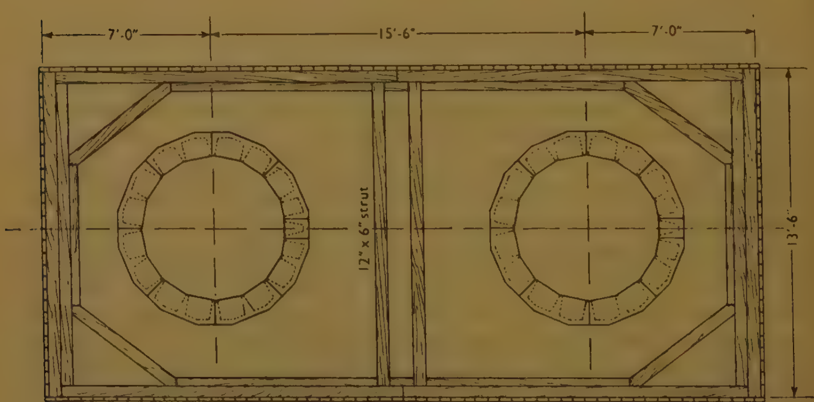
Stage 2.—Only cylinders B1 and C1 of this group were through the beach formation. Of the remaining eight cylinders, E12 and E15, followed by E10 and E11, showed the largest flow of water. It was decided to start compressed-air work on the former two cylinders. Since there appeared to be no signs of ground subsidence during the excavation of E10 and E11, both these cylinders were underpinned to foundation level in the open. Much flow of water was experienced, making work difficult and slow. The flow of water in the remaining four cylinders C2, E16, E17, and E18 was not excessive and it was possible to underpin them in the open also.

Stage 3.—Of the six cylinders in this group, A5, E13, and E14 were never started by the previous contractor and the shafts were sunk by the underpinning method. *Figs 10* show details of preliminary operations for sinking type E shaft. Type A5 shaft was sunk in a similar manner. In E13, E14, and B2, the flow of water was considerable and compressed air would have greatly facilitated the underpinning. By the time the air locks became available the work had progressed to such a stage that it was no longer considered economical to use them. During excavation the surrounding ground showed no signs of subsidence. The remaining

Figs 10



LONGITUDINAL SECTION



PLAN

Scale: $\frac{1}{8}$ inch = 1 foot

DIAGRAMMATIC ARRANGEMENT OF TEMPORARY WORKS FOR THE PRELIMINARY SINKING OPERATIONS OF SHAFTS BY THE UNDERPINNING METHOD

three cylinders were comparatively dry, particularly A4, and they were all underpinned in the open.

The number of cylinders which could be underpinned simultaneously was governed by site conditions. It was not found practicable to work on more than about ten to twelve at a time.

A total of 341 rings was assembled between the 13th March and the 18th December. This gives an average of eight and a half rings per week. The maximum number of rings assembled in one week was sixteen.

Preliminary Operations on Site

The greater part of the site was flooded and it was drained by means of a 4-inch diesel-driven centrifugal pump. The ground was very soft and slushy and could not support the weight of the two 3-ton crawler cranes it was intended to bring to the site. These cranes were to be used for removing the excavation from the bottom of the cylinders. Two crane tracks were constructed (see *Fig. 11*, facing p. 419) consisting of 12-inch-by-6-inch sleepers resting on 12-inch-by-12-inch timbers. Keruing timber was used throughout. As work progressed it was necessary to re-route the crane tracks to open new cylinders or sink shafts.

Stage of Progress of Cylinders Prior to Underpinning

Of a total of twenty-eight cylinders twenty-five had been sunk to various levels by the previous contractor. Cylinders A5, E13, and E14 had not been started. *Figs 12* show the various stages of progress the cylinders were in prior to underpinning them.

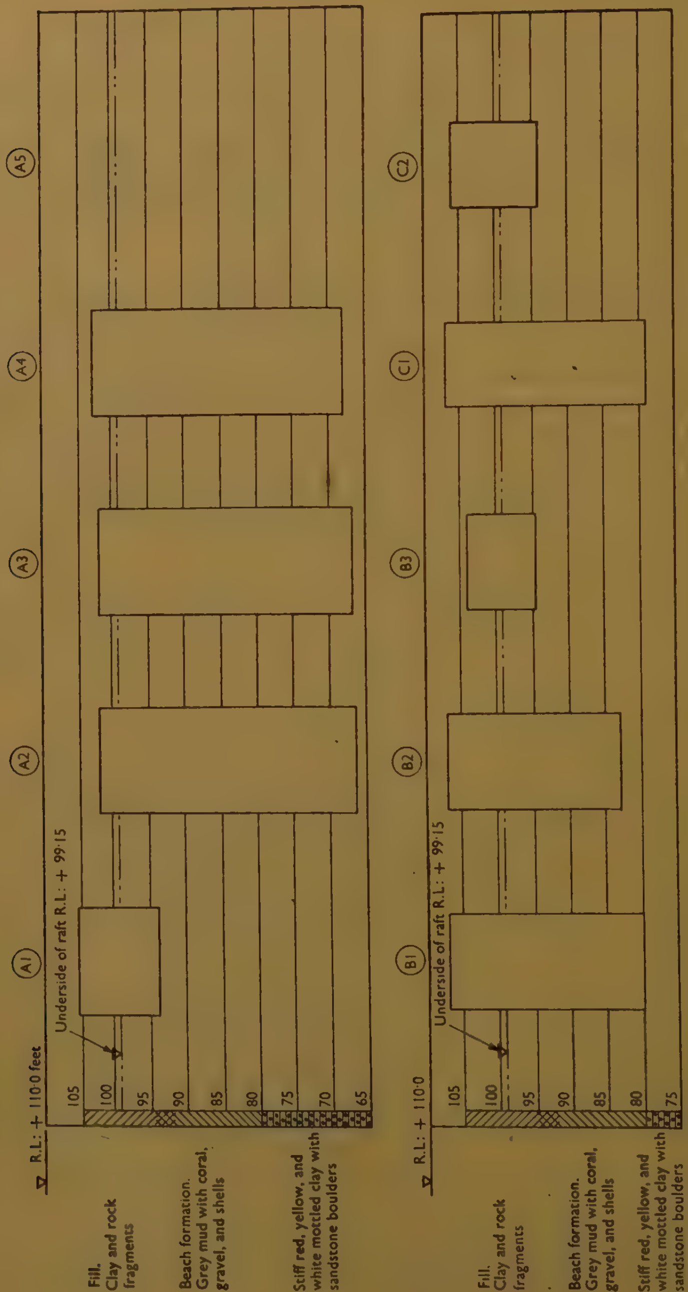
A survey was carried out to measure the inclination of the vertical axes of the cylinders and also to determine the position of their centres. The centres of the tops of the cylinders were measured and the results reduced to a common level corresponding to the underside of the raft, R.L. + 99·15. Fig. 13, Plate 2, shows the displacement of the cylinders relative to their theoretical position. Cylinders E1 and E15 were the worst cases and the resultant displacements were 21 inches and 13 inches respectively. The inclination of the cylinders was nowhere excessive except in cylinders E1 and E15.

It will be observed from the plan of the foundations in Figs 4, Plate 1, that column No. 1 is located very close to the corner of the raft. The inward displacement of cylinder E15 resulted in placing the centre of the column outside the periphery of the cylinder, thus introducing additional stresses. It was necessary to increase the thickness of the raft in this corner by an extra 2 feet, giving it a total thickness of 7 feet. This detail has been omitted from the raft plan (Figs. 4, Plate 1) in order to avoid confusion.

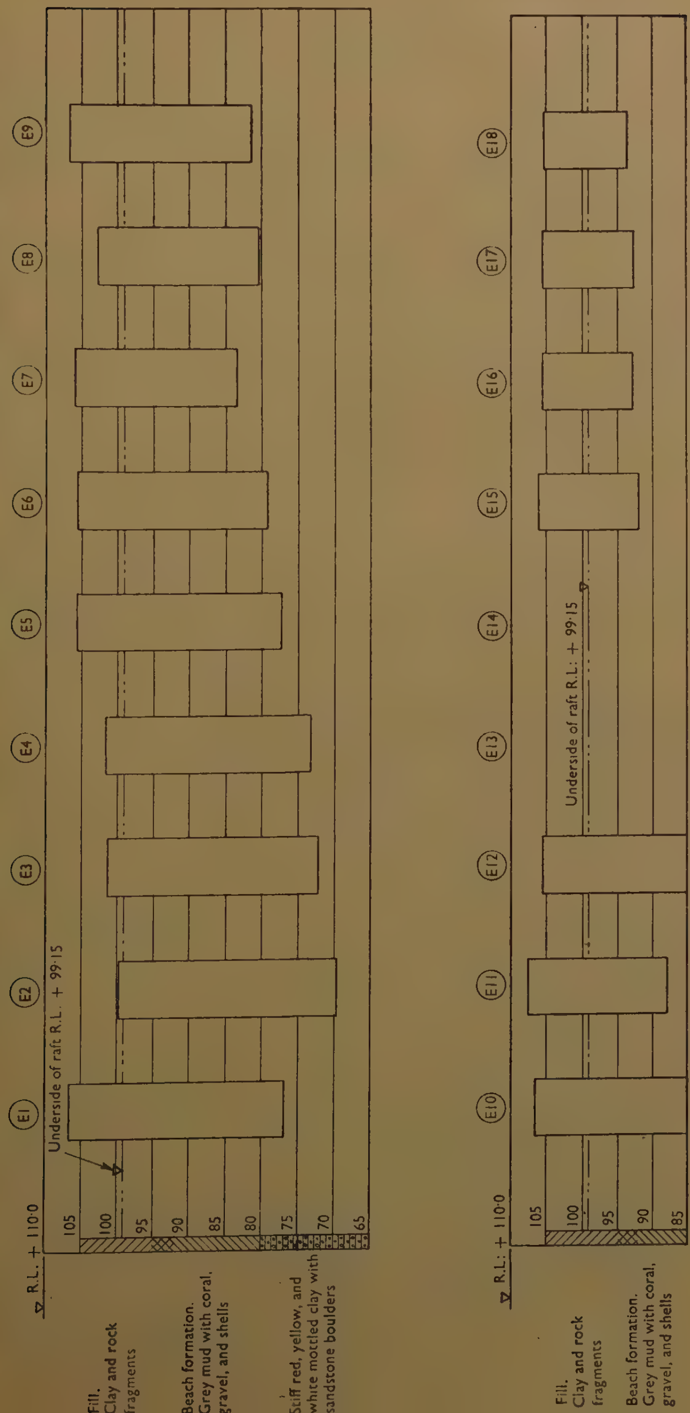
Back-Grouting of Cylinders

Before starting to underpin the cylinders they were back-grouted with neat cement from a level corresponding to the underside of the raft to

Figs 12



R.L.: + 110·0 feet
Underside of raft R.L.: + 99·15
A1
A2
A3
A4
A5
105
100
95
90
85
80
75
70
65
Fill.
Clay and rock fragments
Beach formation.
Grey mud with coral, gravel, and shells
Stiff red, yellow, and white mottled clay with sandstone boulders
R.L.: + 110·0
Underside of raft R.L.: + 99·15
B1
B2
B3
C1
C2
105
100
95
90
85
80
75
Fill.
Clay and rock fragments
Beach formation.
Grey mud with coral, gravel, and shells
Stiff red, yellow, and white mottled clay with sandstone boulders



DIAGRAMS SHOWING DEPTHS OF THE VARIOUS CYLINDERS PRIOR TO UNDERPINNING

the cutting edge. The main object of injecting this grout seal was to keep the ground tight and to prevent water and the beach formation from running between the cylinder walls and the surrounding clay (reference has been made previously to runs of ground). Back-grouting of the cylinders also increased their skin friction, thus reducing the risk of their slipping during underpinning operations. On approaching the bottom of the cylinder the grout was prevented from escaping by packing sand-bags tightly under the cutting edge.

Depending on the size of the cylinder, four to six grouting holes, about 2 inches diameter, were bored through the walls in a horizontal circle. The vertical distance between the holes was about 6 feet. The grouting technique involved wrapping the grouting nozzle with sacking and jamming it tightly into the hole in the cylinder wall. On completing the grouting the nozzle was withdrawn and the hole plugged immediately. The amount of grout lost during the extraction of the nozzle and plugging the hole was not excessive since little pressure could be built up behind the cylinders.

Pressure-Grouting Pans

Two pressure-grouting pans were available. These consisted essentially of a cylindrical container, 18 inches diameter by 2 feet 6 inches long, with a circular hinged lid at the top, locked by means of a pin. Passing through the central axis of the container was a shaft with a series of radial mixing paddles which could be rotated by means of a cranked handle. To operate the grouting pan the container was partially filled with water and cement was gradually added, the paddles being rotated to keep the mix in constant motion. When the grout had reached the consistency of a thick cream the lid was closed and air under pressure was admitted into the container. The grout was forced through the pipe-line at the bottom of the pan and ejected through the grouting nozzle. An air by-pass line fitted to the bottom pipe-line permitted residual grout in the latter to be blown out through the nozzle. The capacity of the grouting pans was about $3\frac{1}{4}$ cubic feet when three-quarters full. The nominal air pressure delivered by the compressors was 100 lb. per square inch, but allowing for leaks and frictional losses the actual pressure of the grout was found to vary between 65 and 70 lb. per square inch.

Excavation

All excavation was carried out by hand. The muck was loaded into skips and hoisted out of the cylinders by means of two 3-ton crawler cranes. The skips, which were of the tilting type, were manufactured locally from $\frac{3}{16}$-inch mild-steel plate. They were 3 feet 6 inches diameter at the top and 2 feet 6 inches diameter at the bottom by 3 feet 6 inches high.

The main tool used by labourers for excavating was the " chongkol " (a hoe). This was satisfactory in soft ground but produced very poor results in the hard clay. Early attempts to introduce pneumatic clay diggers met with little success, but eventually the men were convinced of their

greater speed. The clay diggers proved particularly useful in cutting through the soft coral found in the beach formation.

Blasting of Sandstone Boulders

Early attempts to break up the sandstone boulders encountered in the decomposed shale by means of plug and feathers proved very slow and laborious. Application was made to the local authorities to use small charges of explosives and this was granted. It was most important to ensure that the concussions of the explosions did not break or crack the grout seal between the cylinder walls and surrounding ground.

A number of tests were carried out and it was found that between 1 and 2 ounces of 62 per-cent N/G gelignite per hole gave the most satisfactory results. The number of charges detonated simultaneously was limited to the maximum of four. Electric detonators were used in preference to ordinary detonators. The latter were considered dangerous, since there was always the risk of a man accidentally slipping from the iron ladder as he was climbing out of the cylinder.

Drilling equipment consisted of jackhammers belonging to the 50-lb. class and fitted with a blowing device. Hollow $\frac{7}{8}$-inch-diameter hexagonal drill steels with $1\frac{3}{4}$-inch bits were used for drilling holes. The finished diameter of the holes was just less than 2 inches and the depths ranged from 12 inches to 18 inches. The holes were stemmed with clay cartridges, $1\frac{3}{4}$ inch diameter by 4 inches long.

Blasting was also carried out in those cylinders which were underpinned in compressed air. The procedure was similar to that in open cylinders except that a smaller charge ($\frac{1}{2}$ ounce per hole) of explosive was used and detonation carried out in the open by temporarily releasing the pressure in the air lock. When there was more than one charge to be detonated each one was detonated singly.

Dewatering of Cylinders

One of the most important operations during underpinning was the dewatering of the cylinders. Unless an efficient pumping system was arranged the cylinders would soon fill with water. To minimize any further risk of soil inrush it was important to lower the level of the water in the cylinders gradually and, once lowered, to keep it at that level. With an average of eight to ten pumps running continuously day and night it is probable that the water table was appreciably lowered. A highly contributory factor in the subsidence of the ground during the sinking of the cylinders was the lack of attention given to water keeping by the previous contractor. Work progressed during the day only and at night the pumps were stopped, resulting in the refilling of the cylinders. The persistent rapid lowering of the water in the cylinders at the beginning of each day's work caused a great differential pressure to develop between the inside and the outside of the cylinders. Soft subsoil was forced into the cylinders,

particularly when the excavation was allowed to proceed too far ahead of the cutting edge.

All pumping was carried out with pneumatic sump and sludge pumps. The former is a vertical centrifugal type of pump driven by a vane-type motor. The sludge pump works on the ejector principle and has no rotating parts. The wear and tear on the sump pumps was considerable as a result of high rotational speed combined with the presence of abrasive materials in the water—primarily sand and cement. It was essential to maintain a good stock of spare parts at all times for this type of pump. The sludge pumps proved a more economical proposition in spite of the fact that the particular ones used on this contract suffered from an inherent defect in the flap-valve mechanism. Both types of pumps were operated at a nominal air pressure of 100 lb. per square inch.

Procedure for Underpinning Cylinders

Underpinning details for the four different types of cylinders are shown in Figs 5, Plate 1. The segmental rings or linings are similar in each case except for the diameters, the number of rings, and the number of segments per ring.

All rings are encased in a secondary reinforced-concrete lining. In cylinders type E the secondary lining ends in a plain circular opening at the top, whereas in the larger cylinders the top is stiffened by a cruciform diaphragm 1 foot thick.

Most of the cylinders rest on "special" slabs 2 feet thick. The object of introducing these slabs was to obtain a more sudden increase in base area than that offered by the segments. This was found particularly useful in those cases where, having reached foundation level, it was necessary to expand the base with the minimum of excavation.

Before underpinning proper could commence it was necessary to provide a firm anchorage between the cylinder and the first ring of segments. The method adopted for achieving this object is shown in the cutting-edge detail in Figs 5, Plate 1. After clearing the inside of the cylinder a series of 2-inch-diameter holes were drilled just above the cutting edge. The holes were distributed at the rate of two for every top bolt-hole in the segments. Into the holes were grouted 1-inch-diameter rag-bolts. Excavation was then continued to a depth of 2 feet 6 inches below the cutting edge. The ground was levelled and the first ring of segments assembled under the cutting edge. Positive anchorage between the segments and the cylinder was provided by means of 1-inch-diameter bolts bent as shown and with one end hooked. The hooked end fitted over one of the rag-bolts and the other end was bolted to the segment. The collar reinforcement, consisting of $\frac{1}{2}$-inch and $\frac{7}{8}$-inch diameter bars, was placed in position and the concrete collar was cast. Two or three days later neat cement grout was injected behind the collar through the grouting holes in

the segments. Gunny sacks were packed tightly under the segments to reduce leakage of grout to the minimum.

The only element of risk involved in securing the first ring of segments to the cylinders was the possibility of the latter slipping during excavation and the casting of the collar. Fortunately no such incidents occurred in any of the cylinders, except in B3 which slipped 17 inches. The reason for this was probably the fact that the night shift had omitted to back-grout the cylinder. The cylinder was short, only about 10 feet in depth, and projected slightly above ground level. The skin friction was insufficient to retain it in position during excavation. Before underpinning operations could be resumed it was necessary to prop the cylinder.

In assembling the subsequent rings the same degree of risk was not taken. Only two or three segments were undercut at a time, the segments of the new ring were bolted to the ring above and the next two or three segments undercut. This procedure was continued until the ring was completed. Grouting operations were repeated as before, taking the same precautions against leaks. In soft ground it was necessary to grout each ring as it was completed, but in firmer ground the rings could be grouted in groups of two or three.

Prior to starting underpinning the cylinders, consideration had been given to the use of bituminous packing in the longitudinal and circumferential joints, and grummets under the bolt washers, with a view to ensuring even distribution of bearing pressure over the flange faces and also to reduce leaks to the minimum. Since the conditions in this case were not so exacting as those encountered in tunnels, it was decided to omit all packing and grummets. With regard to leaks, a small flow of water could be tolerated. In practice, this arrangement proved quite satisfactory in most cylinders except B2, E10, E11, E13, and E14, where the flow of water between the flanges was quite considerable. It should be mentioned at this stage that according to the original programme it was intended to underpin these cylinders in compressed air but, owing to circumstances prevailing then (see p. 21), it was not possible to do so. Continual injections of grout behind the segments did not materially reduce the flow of water. A great proportion of the grout escaped through the joints. This loss was attributed to a certain extent to the high grouting pressure used (65 to 70 lb. per square inch). It was therefore decided to reduce the grouting pressure and introduce $\frac{1}{8}$-inch bituminous packing between the flanges. Grout losses were considerably reduced. Grout at a lower pressure was obtained from a "Colcrete" colloidal mixer capable of developing a pressure of 15 lb. per square inch. To this pressure should be added the head of grout from the mixer down to the point of injection.

Sealing of Cylinder Bases

As the last ring of each cylinder was completed, the bottom was sealed with either a "special" or an "ordinary" slab. These slabs or bases

have already been referred to. In order to construct the "special" slabs it was necessary to undercut the last rings by amounts ranging from 12 inches to 2 feet 3 inches. This work presented no difficulties except in a few isolated cases. In cylinder E15, for example, the ground behind the last ring was continually collapsing. Some form of support for the ground was necessary which would not seriously interfere with the concreting of the "special" slabs. Short planks, measuring 6 inches by 1 inch by 3 feet were bolted at one end to the bottom flanges of the segments, leaving the other end to project radially outwards into the excavation and thus support the ground above. The bottom slab was then concreted leaving the timber supports in position. To avoid having to leave the cylinders unsupported during excavation the "special" slabs were concreted in sectors leaving the central portion until last.

Emphasis was placed on the importance of keeping the bottom of the cylinders free of water during excavation, particularly immediately before casting the bottom slab, in order to avoid softening and swelling of the clay. Unfortunately, owing to the constant percolation of water through the joints between the segments, it was extremely difficult to observe these precautions. There was always a certain amount of water present in spite of the fact that the pumps were kept running continuously. Softening of the clay did not appear serious, but as a precautionary measure, however, it was decided to inject grout under the base slabs and thus prestress it. The excavation was deepened by 15 inches below the underside level of the base slab and covered with a 9-inch-thick layer of 9-inch to 6-inch granite blocks. Over this was laid $1\frac{1}{2}-\frac{3}{4}$-inch crushed granite to a depth of 3 inches followed by a carpet of lean concrete 2 to 3 inches thick. These details are shown on Figs 5, Plate 1. Four to six $1\frac{1}{2}$-inch grouting pipes were placed in a circle concentric with the base. After completing the cylinders, including the secondary lining encasing the segments, grout was injected under the base at a pressure of about 70 lb. per square inch.

Secondary Lining

After completing the concreting of the base slab, the segmental rings were encased in a secondary reinforced-concrete lining. The thickness of this lining, including the segments, varied from 18 inches to 3 feet 6 inches, according to the size of the cylinder. The concrete mix was 1 : 2 : 4 and consolidation was by means of pneumatic immersion vibrators. The circular formwork was divided into a convenient number of equal arcs to form panels about 3 feet wide by 3 feet 6 inches high. The timber panels were lined with 22-gauge galvanized iron, thus allowing continual re-use. The lining was concreted in lifts of 3 feet.

The concrete was conveyed to the required point in the cylinder by means of an "elephant's trunk." This consisted of a shallow hopper about 5 feet square by 2 feet deep resting on the top of the cylinder. At the bottom

Fig. 15

" Barking " Air-Lock in Operation over Cylinder E15

Fig. 17

View along Finlayson Green Boundary, showing Shoring of Roadside before Reinstatement

Fig. 18

General View of Site from K.P.M. Building, showing Reinforced-Concrete Raft nearing Completion. Crane in Foreground was used for erecting Steelwork (27 January, 1953)

of the hopper was welded a short length of 9-inch diameter pipe to which 10-foot-long pipes of the same diameter were attached by means of hooks and eyes. The top of each pipe was flanged and the bottom plain. The pipes hung freely inside the cylinder and the bottom one could be pulled in any direction where the concrete was to be discharged.

Underpinning in Compressed Air

Apart from the added precautions pertaining to the operation of air-locks, the procedure for underpinning in compressed air was similar to that in open cylinders. A diagrammatic arrangement of the two air-locks, the "Dorman Long" type and the "Barking," fitted to cylinders E12 and E15 respectively, is shown in *Figs 14*, p. 436. The Dorman Long air-lock has a single man-lock capable of passing four men at a time. The "Barking" lock was so called by the suppliers because they had used it on a cable tunnel under Barking Creek, and to distinguish it from the Dorman Long type. The air-lock is of the vertical type (see *Fig. 15*) which combines man- and muck-locks. The platform at the top was fabricated locally.

Both air-locks were secured to the cylinders by means of a reinforced-concrete air deck, 1 foot thick, as shown in *Figs 14*. Positive anchorage between the air deck and cylinder was achieved by cutting out a chase 4 inches deep by 12 inches wide round the inside wall of the cylinder and casting the air deck across it. The figure-of-eight air shaft was then bolted to the air deck. A rubber packing, 1 inch thick, was inserted between the air shaft and air deck to prevent air leaks. Compressed air was supplied through a 3-inch non-return valve in the air-lock and conducted to the bottom of the cylinder through a 3-inch pipe which was gradually extended as excavation progressed. The correct air pressure inside the air-lock was maintained by controlling the opening of a relief valve on the side of the air-lock. A pressure gauge was fitted to each air-lock. High-pressure air at 100 lb. per square inch for the operation of pneumatic tools was supplied through a second 3-inch flanged opening in the side of the air-lock. The air was conveyed to the bottom of the cylinder through a $\frac{3}{4}$-inch pipe.

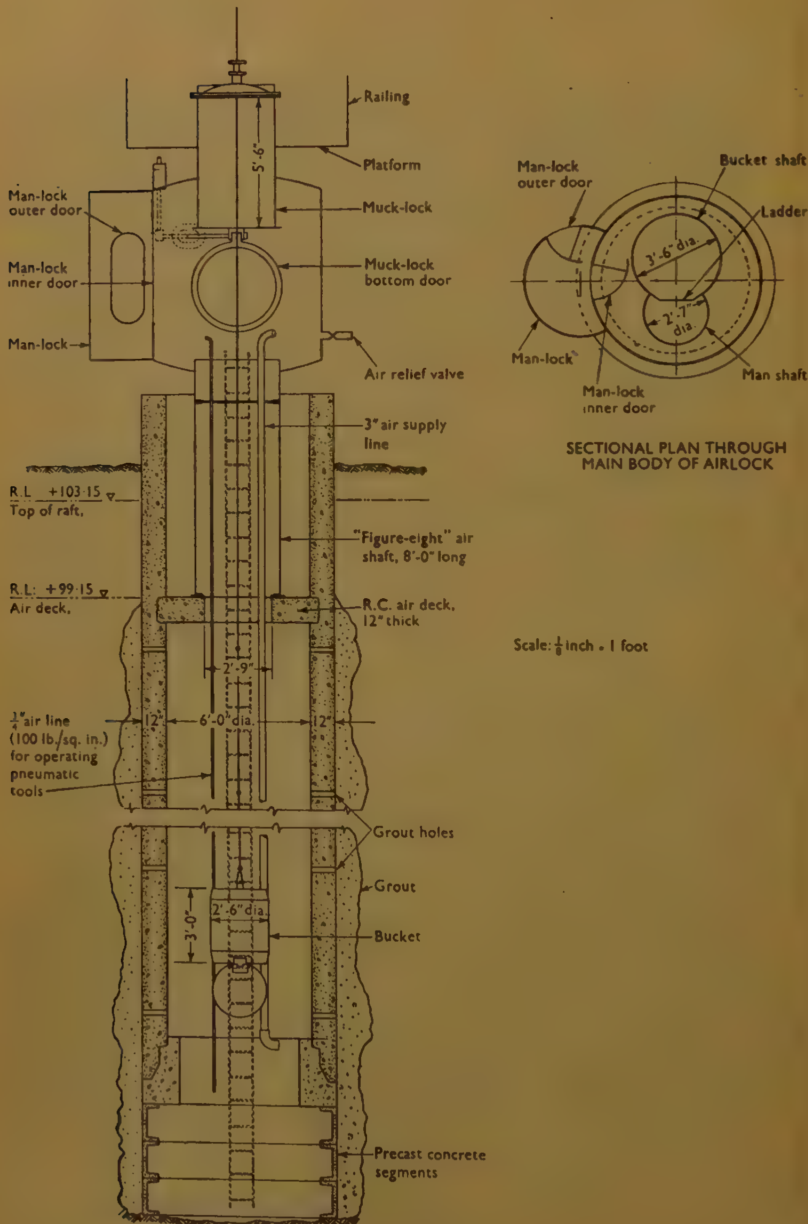
During grouting operations the high-pressure air line was disconnected inside and outside the air-lock and replaced by a $2\frac{1}{2}$-inch high-pressure suction rubber pipe. The outside pipe was connected to the grouting pan and the inside one was sufficiently long to extend to the bottom of the excavation. The grouting pipe was sometimes used as a "snorer" to expel surplus water which might collect at the bottom of the excavation.

Provision was also made for electric light, fresh water, and a telephone.

The upthrust due to the air pressure inside the cylinder was balanced by cast-iron ballast and by water inside the annular space between the cylinder and the air shaft.

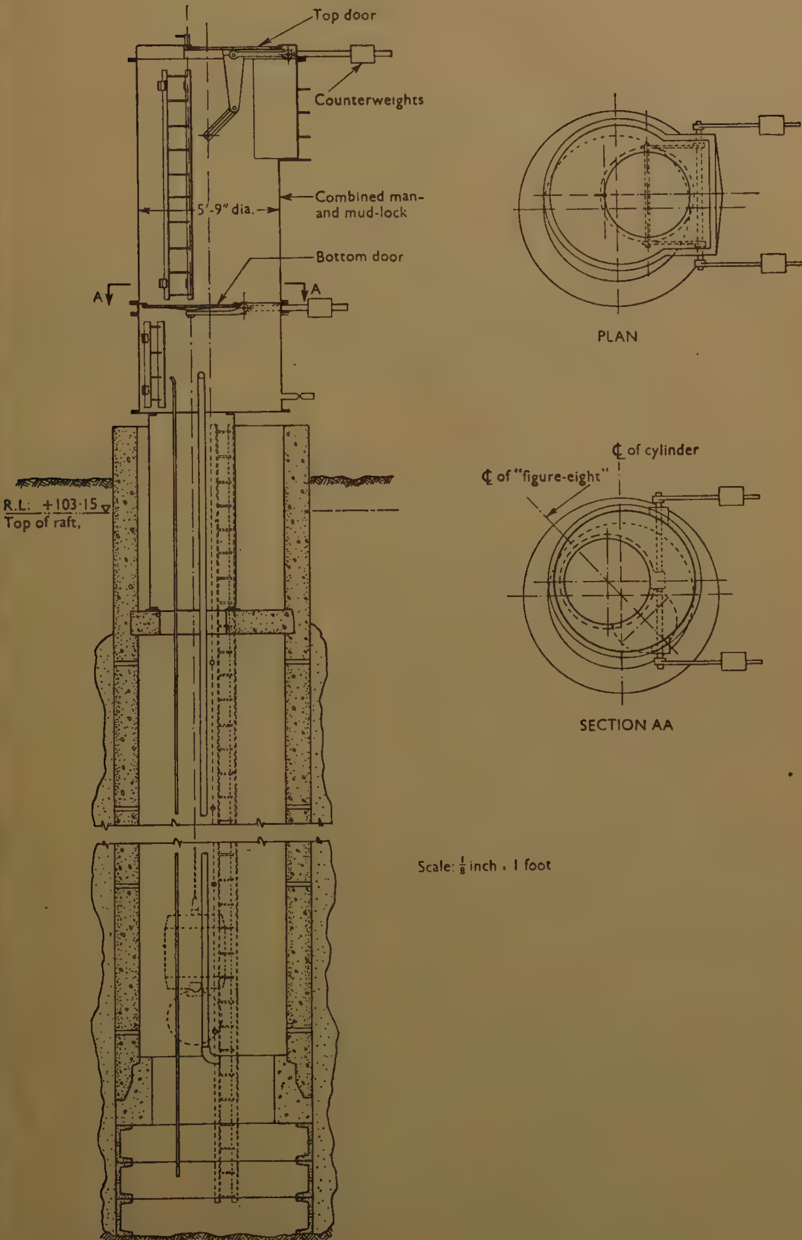
The signalman, who was permanently stationed inside the muck-lock, conveyed his instructions to the crane driver by means of a system of coloured lights outside the air-lock. These lights, which were under his

Figs 14 (a)



" DORMAN LONG " TYPE AIR-LOCK FITTED TO TYPE E CYLINDER

Figs 14 (b)



"BARKING" TYPE AIR-LOCK FITTED TO TYPE E CYLINDER

control, were duplicated on his switchboard. Indications to lower or raise the bucket in the air-lock were conveyed by flashing a green or white light respectively. Instructions to arrest hoisting were conveyed by flashing a red light.

In addition to the signalman inside the air-lock, two muck-lock operators were stationed on the top platform and a fourth man controlled the air pressure inside the air-lock by manipulating the relief valve on the outside.

Air-Conditioning Plant for Compressed Air Work

The Island of Singapore is located in a tropical region approximately 1° North of the Equator. The climate of the Island is characterized by the uniformity of high temperature throughout the day and the year, copious rainfall, and high humidity. The mean temperature variation is from 76° F. to 86° F. and the relative humidity ranges from 63 to 95 per cent, producing enervating conditions. Since human comfort depends on the cooling effect of evaporating perspiration and this, in turn, on the movement of air, it becomes extremely uncomfortable to work in closed or sheltered places.

In view of the climatic conditions prevailing in Singapore, and also of the fact that the air for pneumatic work was to be compressed up to a maximum pressure of 15 lb. per square inch above atmospheric pressure, it was considered necessary to introduce an air-conditioning plant. The plant was designed so that the temperature of the air entering the air-lock was 4 or 5° F. below the outside temperature. The relative humidity was also reduced by about 10 per cent.

Local Labour's Reaction to Compressed Air Work

Since the pressure inside the air-lock never exceeded 10 lb. per square inch, no caisson disease was experienced. At these low working pressures rapid compression and de-compression of the men was possible. The men worked 8-hour shifts in 24 hours. During the early stages of compressed air work, some of the men were noticed to bleed slightly from the nose on being de-compressed. This bleeding disappeared after a while.

Since this was the first time that compressed air work had been carried out in Singapore, certain initial difficulties were encountered in obtaining the necessary labour. Of a total of about sixty men subjected to compression tests twenty men were selected; two of them were employed as rock drillers and the remainder were divided between the two air-locks.

Interference Between Cylinders

As a result of the "belling out" of the bases of the shafts a certain amount of interference between the segmental rings and base slabs was unavoidable. This is shown in Fig. 16, Plate 2. There were only four

cases where interference between rings, as distinct from interference between base slabs, occurred. They were between cylinders B1 and E10, B2 and E11, C1 and E18, and C2 and E16. The greatest degree of interference occurred between the last two cylinders in the above group. Interference between rings in cylinders B2 and E12 was negligible.

The constructional procedure adopted where interference between rings occurred was to complete the underpinning of one cylinder in the normal way. As many complete rings as possible of the adjacent cylinder were assembled and the subsequent rings would abut against those of the first cylinder, the free ends of the uncompleted rings were secured together by means of $\frac{5}{8}$-inch-diameter mild-steel tie-rods bolted to the longitudinal flanges of the segments. The tie-rods were only very slightly strained to avoid damaging the flanges. Stirrups of $\frac{1}{4}$ inch diameter were wrapped round the tie-rods, and the area between the free ends of the rings was concreted.

Reinforced-Concrete Raft

As the cylinders approached completion the site was excavated and levelled to a depth of 3 inches below the underside level of the raft, and a 3-inch screed of lean concrete was laid over the area.

The existing timbering to the faces of the excavation was extremely precarious, and matters were further complicated by the fact that additional lateral support for the walings had been provided, presumably during the subsidence of the road, by strutting them against the cylinders at points above raft level. This can be seen in *Fig. 17*, facing p. 434. The timbering had to be reinstated before these cylinders could be cut down to raft level.

All cylinders were cut down to the level of the underside of the raft with 80-lb. pneumatic concrete-breakers. All surplus reinforcement in the cylinder walls was removed, leaving only the vertical bars to project about 3 feet 6 inches into the raft.

The raft, which is shown in Figs 4, Plate 1, consists of a system of reinforced-concrete beams, mainly 4 feet thick except under the column grillages where it is 5 feet thick. Under column No. 1, which is located very near to the corner of the raft, the thickness is 7 feet. The top of the raft is at R.L. + 103·15 which is basement level and is also the level of the top of the stanchion base plates. The voids between the beams are spanned by 8-inch reinforced-concrete slabs seated in 8-inch-by-4-inch recesses on the edge of the beams and anchored to the latter by means of $\frac{3}{4}$-inch-diameter reinforcement at 8-inch centres. Additional reinforcement, in the form of sixteen R.S.Js ($I = 3{,}340$ inches ^{4} each), was introduced in the raft over cylinders E16, E17, and E18 to distribute the heavy stanchion loads of the steel superstructure in this area.

The beams were concreted in sections, limiting the volume of concrete of each section to about 70 cubic yards. As the beams were completed

the voids between them were filled with granite dust to the underside level of the 8-inch slab and the slab was cast. The granite dust was well consolidated in layers of 6 to 12 inches thickness. *Fig. 18*, facing p. 435, shows the raft under construction. All concrete in the raft was of nominal 1 : 2 : 4 mix using $1\frac{1}{2}$ – $\frac{3}{8}$-inch graded granite for coarse aggregate. Consolidation of the concrete was by means of air-operated immersion vibrators. Concrete test cubes were taken at regular intervals and crushing strengths of between 3,000 to 4,000 lb. per square inch at 28 days were obtained. Two, and during the latter stages, three 10/7 concrete-mixers were used for concreting. The concrete was distributed by means of side tipping wagons. This arrangement can be seen in *Fig. 18*.

Base Plates and Grillages

Recesses were provided in the raft for a total of forty-six column base plates and grillages. The base plates and grillages vary in size according to individual columns, the two heaviest weighing nearly 2 and 3 tons respectively. They were set to the correct level by packing mild-steel plates under them at three points and were then levelled and aligned. The mild-steel plates were 9 inches by 4 inches and a selection of thicknesses of from $\frac{1}{64}$ inch to 1 inch was available. A 1 : 1 cement/sand grout was used for grouting all base plates and grillages. The grout was mixed by means of a " Colcrete " colloidal mixer.

Labour

All labour, 95 per cent of which was Chinese, was recruited locally and trained by two British foremen flown out from England. Unskilled labour was supplied by a subcontractor and skilled labour employed direct by the contractor. A number of female coolies were also employed.

This was the first time work of this nature had been undertaken in Singapore, and on the whole the men gave quite satisfactory service. The initial difficulties in trying to get the men to work in compressed air is understandable. They were somewhat apprehensive of the conditions under which they were expected to work.

The daily labour requirements were based on the number of cylinders under construction at one time. It was not found practicable to use more than three men for excavating and underpinning each of the small cylinders (type E); the other three types required five men each. Grouting operations required six or seven men. Two men would control the grouting at the bottom of the cylinder and the remainder would fill and operate the pressure-grouting pan. Approximately twenty female labourers were available for concreting and/or excavating. Drilling and blasting was carried about by a gang of about five men. This number was reduced during the night shift since no blasting was carried out at night. Five or six fitters were responsible for dewatering the cylinders and for the general

operation and maintenance of the pumps. Fixing and stripping of shuttering to the internal lining of the cylinders was carried out by about six carpenters. Owing to lack of space on the site, all reinforcement was cut and bent at the contractor's yard and transported to the site on lorries and trailers. Four to six men were employed to tie the reinforcement in position. To the above must be added crane, lorry, and compressor drivers, repair machine shop fitters, electricians, and watchmen.

Work progressed 24 hours per day and all unskilled labour worked 8-hour shifts. Female labourers were employed mostly on the day shifts only, although there were occasions when they were employed on the evening shifts. All fitters, engine drivers, and crane operators worked in shifts of 12 hours.

Plant

The greater proportion of the plant and tools used in the execution of this contract was of British manufacture, and the remainder American. The following equipment was available :—

One 3-ton crane fitted with 18-foot jib and mounted on pneumatic tires.

Two 3-ton diesel crawler cranes fitted with 35-foot jibs.

Three 10/7-cubic-foot-capacity diesel-driven concrete-mixers.

One " Colcrete " petrol-driven colloidal mixer with a rated output of 240 cubic feet of grout per minute.

Eight sump pumps, and three sludge pumps operated by compressed air and capable of delivering 75 gallons of water per minute against 100 feet head at an air pressure of 100 lb. per square inch.

Five 80-lb. concrete-breakers and two 30-lb. rippers or clay diggers.

Five 55-lb. rock drills with automatic rotation and hole-blowing device.

Three 45-lb. and one 15-lb. internal pneumatic concrete-vibrators with frequencies of 8,000 and 6,000 vibrations per minute.

Two pressure-grouting pans, manually operated, with a capacity of $3\frac{1}{4}$ cubic feet when three-quarters full. (Hand-mixing of the grout proved to be slow and, in order to speed up output, the cement and water were pre-mixed in a roller type of " Colcrete " colloidal mixer, and then poured into the pressure-grouting pan.)

Power and Air Supply

During the construction of the foundations, Singapore suffered from frequent electric power cuts owing to the shortage of electricity. The new power station at Pasir Panjang was still under construction. It was, therefore, necessary to supplement the city's meagre supply of electricity with power from two stand-by generators.

The power house was equipped with two 75-kilowatt diesel generators, each of 124 horse-power. Current for power was supplied at 400 volts, 3-phase, 50 cycles per second, and lighting current at 220 volts. The generators were used mainly to supply current to the electrically driven low-pressure compressor. Low-pressure air was supplied to the air-locks from a rolling-drum rotary compressor, driven by an 185-brake-horse-power electric motor directly coupled to it. The compressor had a capacity of 1,800 cubic feet of free air per minute at a working pressure of 15 lb. per square inch.

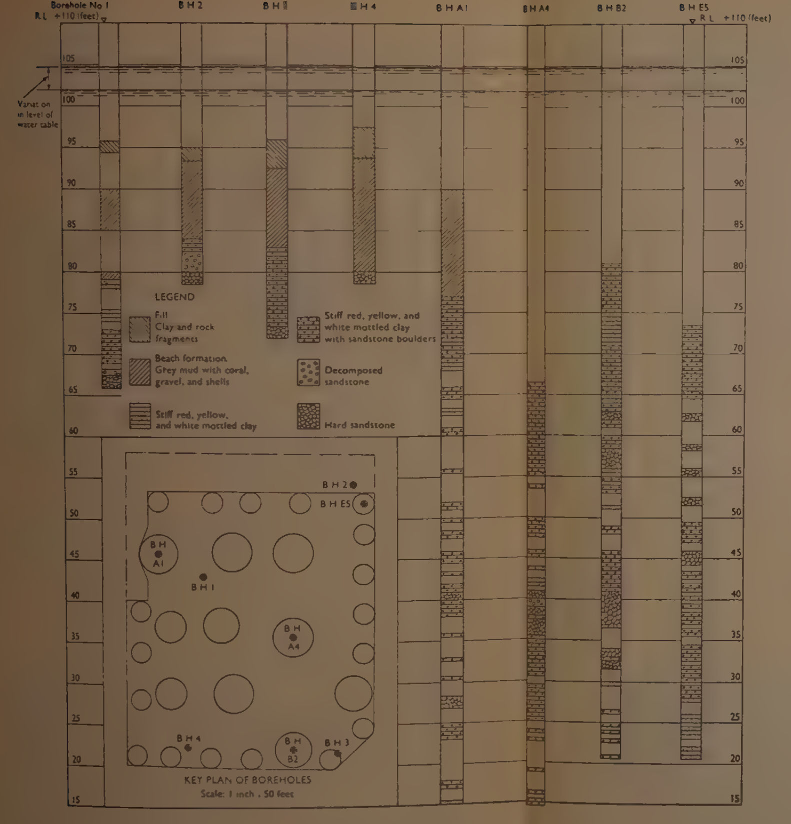
High-pressure air for the operation of pneumatic tools and pumps was supplied by two mobile compressors, driven by 145-brake-horse-power diesel engines at 1,350 revolutions per minute. These compressors, which were of the two-stage air-cooled type, were capable of delivering 620 cubic feet of free air at a maximum working pressure of 100 lb. per square inch. They had been modified by the makers to enable them to be used as single-stage compressors delivering 700 cubic feet of free air per minute at a maximum pressure of 40 lb. per square inch. The object of this modification was that, in the event of the rolling-drum compressor breaking down, these two machines could be substituted. Such an emergency did occur on one occasion only when the radial sliding blades of the low-pressure compressor seized in the rotor slots. During repairs high-pressure air was supplied from a mobile compressor.

Air-Conditioning Plant

An air-conditioning plant was used for cooling and de-humidifying the low-pressure air prior to its entry into the air-locks. The equipment consisted of a pre-cooler and de-humidifier fitted to the suction side of the rolling-drum compressor and an after-cooler on the discharge side.

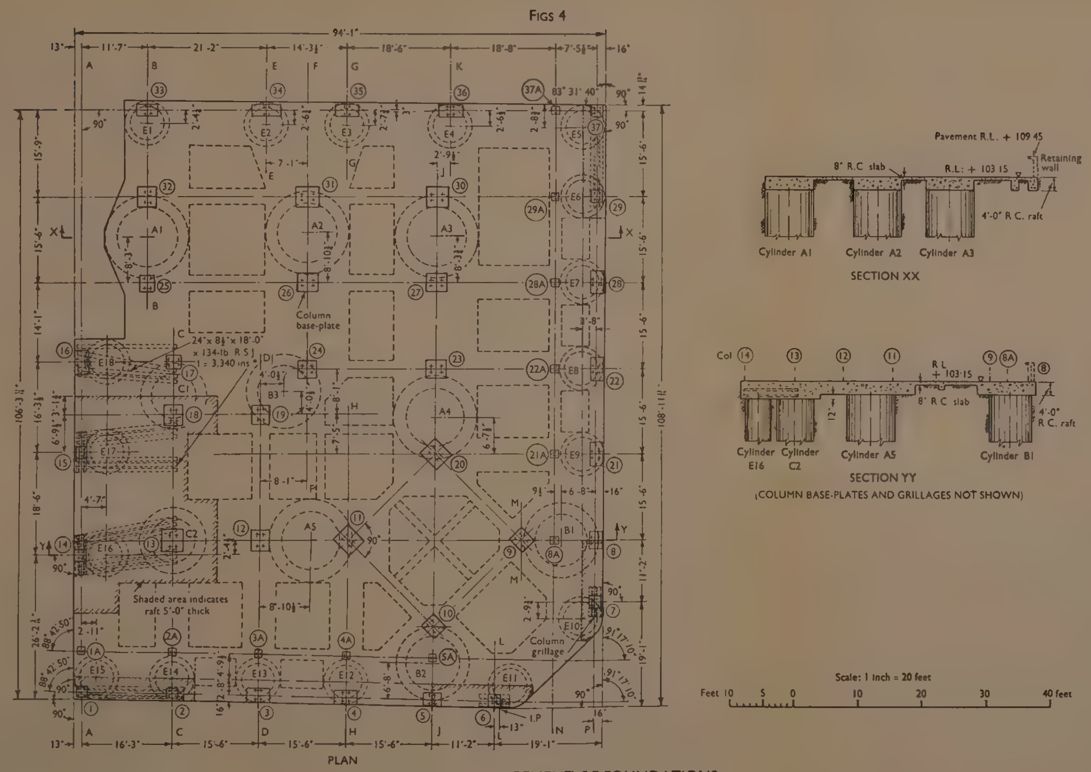
When the air-conditioning plant had been working for about a month a gradual rise in the outlet air temperature was noticed. It was discovered that a substantial quantity of lubricating oil from the compressor had accumulated in the after-cooler, covering the cooling coils with a thin film of oil and thereby reducing their effectiveness. The after-cooler had to be dismantled and cleaned and, to prevent a similar recurrence, two oil removers in series were installed between it and the compressor.

The oil removers, fabricated locally in mild steel, were designed on the same principle as an Archimedean screw. Each oil remover consisted of an 8-inch-diameter tube, 4 feet long, with an airtight spiral inside of 6 inches pitch. The tube was located in the horizontal position. Air, as it passed through the spiral, lost by impact a large proportion of the oil which collected at the bottom of the tube. Outlet pipes of $\frac{3}{4}$ inch diameter, located at the bottom of the tube at the same pitch as the spiral, were connected together by a common pipe and the surplus oil was blown away through a regulator valve. The same device was used to remove water from the high-pressure air prior to distributing it to the various pneumatic tools.



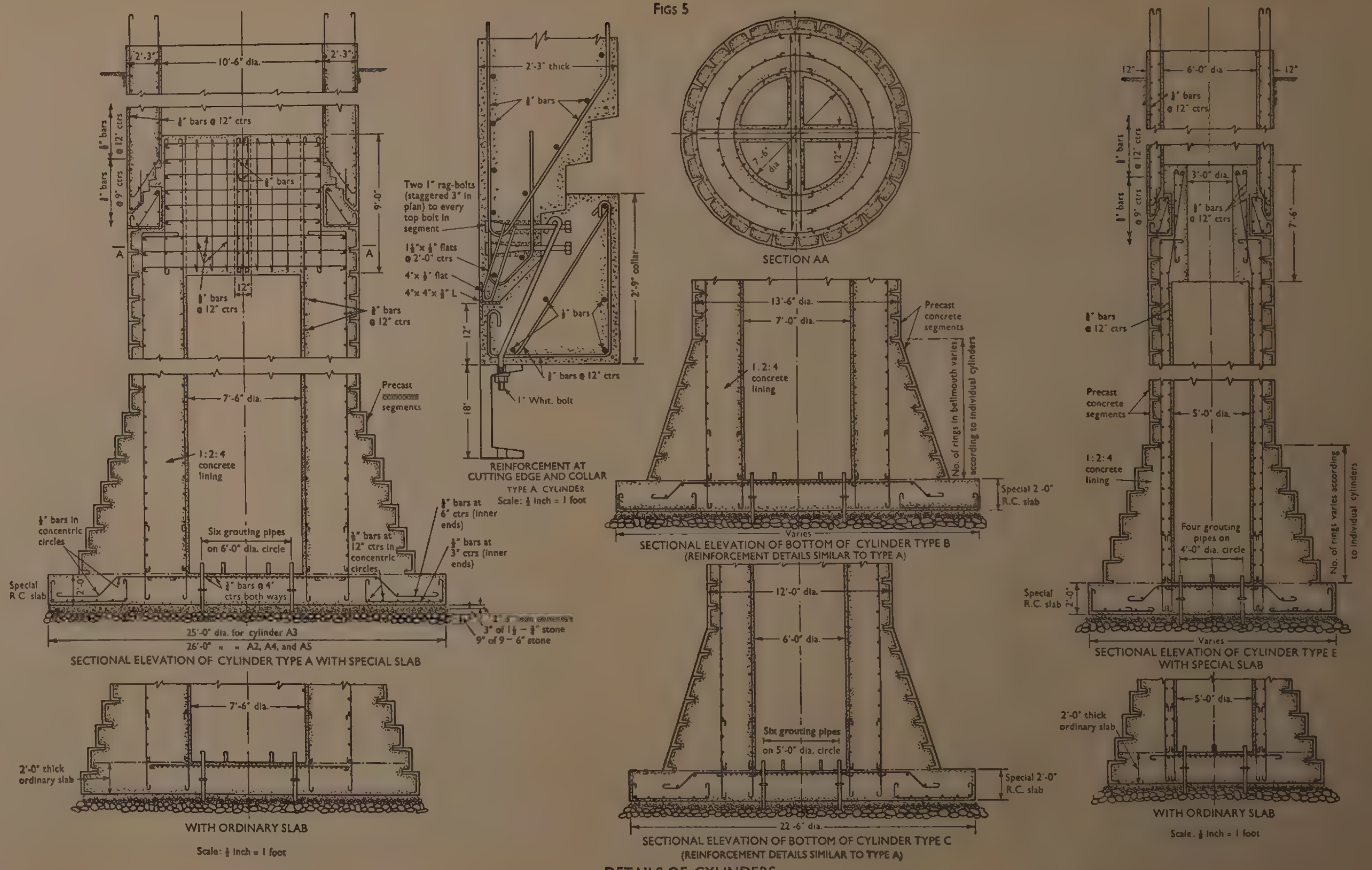
GEOLOGICAL DATA

Figs 4



GENERAL ARRANGEMENT OF FOUNDATIONS

Figs 5



DETAILS OF CYLINDERS

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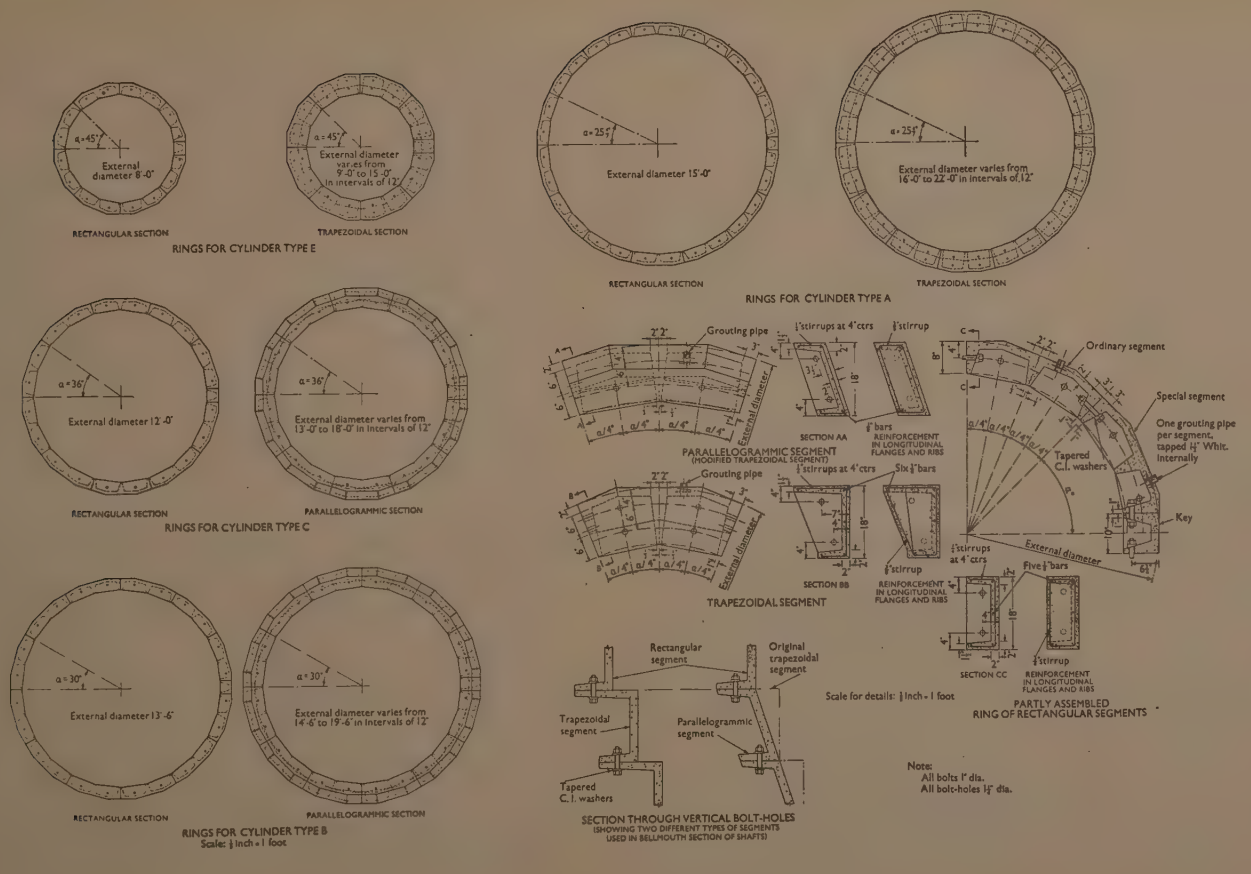
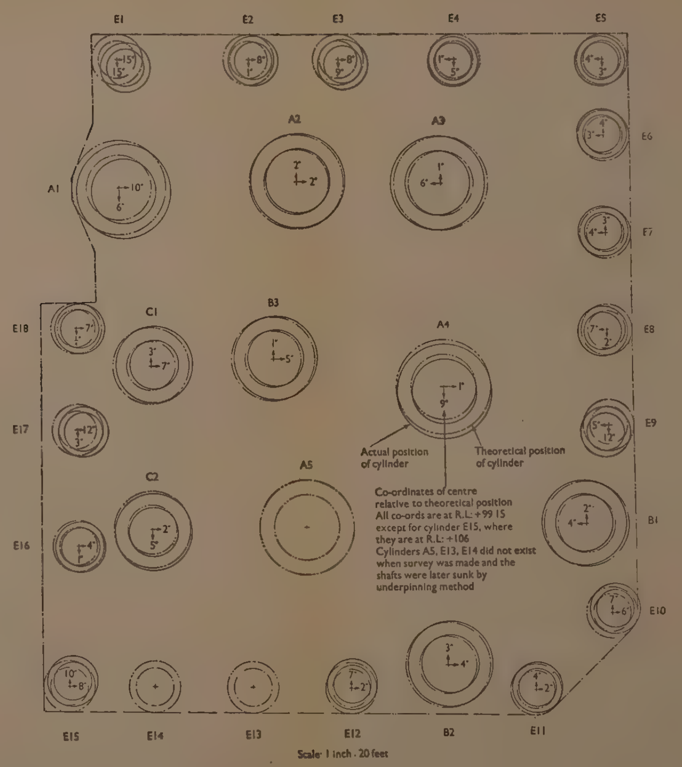
THE HISTORY AND CONSTRUCTION OF THE FOUNDATIONS OF THE ASIA INSURANCE BUILDING, SINGAPORE

FIGS 8



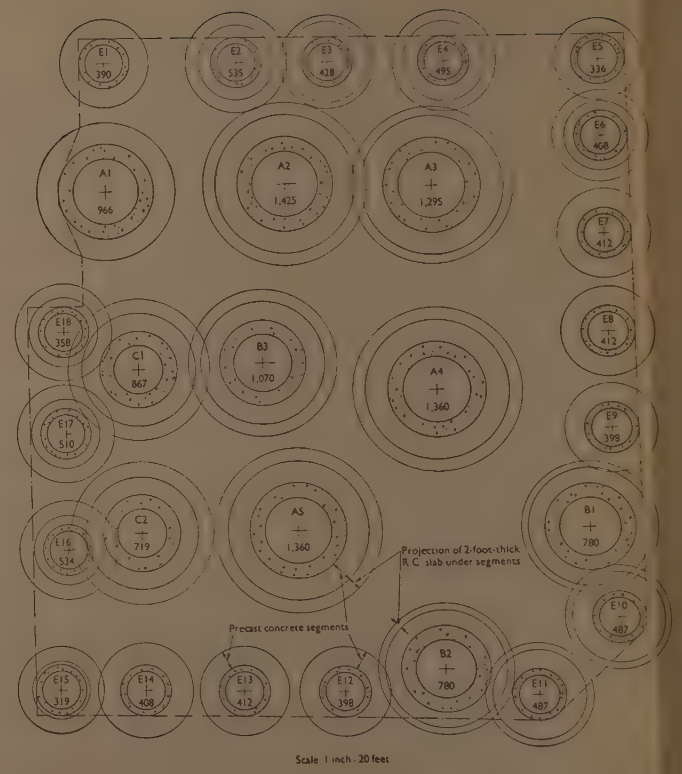
PRECAST CONCRETE SEGMENTAL RINGS FOR UNDERPINNING CAISSONS

FIG. 13



PLAN OF FOUNDATIONS SHOWING RELATIVE DISPLACEMENT OF CYLINDERS AT RAFT LEVEL

FIG. 16



PLAN OF FOUNDATIONS SHOWING INTERFERENCE BETWEEN CYLINDERS AND LOAD (IN TONS) CARRIED BY EACH CYLINDER

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Costs

The underpinning of the cylinders, including the reinforced-concrete raft, was carried out on a cost-plus-profit basis. The total cost of the foundations, including the partial sinking of the cylinders, was approximately \$2,600,000 (Straits). The cost of the underpinning, exclusive of Consulting Engineer's and Architect's fees, was approximately \$2,140,000 (Straits).

Acknowledgements

The Asia Insurance Building is being built for the Asia Insurance Company Ltd in Singapore.

The Author is indebted to the Consulting Engineer, Mr Steen Sehested, B.Sc.; the Asia Insurance Company Ltd; the Contractors, Messrs Gammon (Malaya) Ltd; Messrs Soil Mechanics Ltd; the Architect, Mr Ng Keng Siang; Messrs Ewart & Co. Ltd who carried out the diamond drilling; and the President of the City Council of Singapore for permission to present this Paper.

The Author wishes to thank, in particular, Mr Steen Sehested for providing most of the data relating to the design and history of the foundations.

Mr J. B. Murray, B.Sc., M.I.C.E., was the Contractors' Managing Director responsible for the planning and organization. Mr E. D. H. Johnstone and the Author were respectively the Contractors' Agent (part-time) and Engineer in charge of the underpinning of the foundations.

The Paper is accompanied by twenty-one photographs and fifteen sheets of drawings, from some of which the half-tone page plates, folding Plates 1 and 2, and the Figures in the text have been prepared.

Discussion

Mr Rudolph Glossop remarked that the Paper showed how important it was, when dealing with foundation problems in difficult ground, to choose the right method; that choice could only be based on careful site investigation. If the right method were chosen all would go well and to programme; if the wrong method were chosen, there would be nothing but trouble throughout the job. The simple fact in the case in question was that caissons had not been the right answer because there were big boulders in the ground, so that the operation had been doomed from the start.

Another point of interest to engineers who had spent their lives in England was that even in a big city like Singapore troubles arose from lack of suitable plant and key men. There was no doubt that all the

troubles experienced in connexion with the Asia Insurance Company Building resulted from the fact that no diamond drilling equipment was available in Singapore. If there had been, the consulting engineer would have used it, and would doubtless have adopted a different design.

The Paper interested him also because it dealt with one of the few cases within Mr Glossop's knowledge where segmental shafts had been used for foundations. To the tunnel engineer they were very familiar structures. By a curious chance, however, in 1951, his colleague Mr Harding and he had been preparing a Paper for the Building Congress held in London, and had been going through various types of structure used in foundation work. They came to the question of segmental shafts, and had had considerable discussion whether those could be regarded as normal expedients for foundation work; they had been inclined to decide that they could not be regarded in that way. One instance of their use which they had known at that time had been for the National Provincial Bank building in the 1920's, when Sir Harley Dalrymple-Hay made use of shafts because the site, like that described by the Author, had been very congested; it had been essential not to lose ground, and Sir Harley wanted to support every inch of ground as he went down.

Within a month, however, they had had a letter from the Municipal Engineer of Hong Kong referring to the very building which the Author had described, and after reading that letter and looking at the drawings, they had come to the conclusion that, by an extraordinary chance, that was an example where the segmental shaft used, of course, with compressed air unquestionably was the right answer. Afterwards, his colleague, Mr Wild, had gone out to Singapore, carried out a site investigation, and discussed the problem with the architect and consulting engineer; eventually the scheme which the Author had described had been produced.

Generally speaking, then, the segmental shaft was the answer where there were very difficult conditions of running sand with high water-pressure and large boulders, which made it impossible to use bored piles, caissons, steel sheet-piling, or anything else. With compressed air, there was complete control of the face. If there was a boulder it could be got out without losing too much ground, and the ring could be built and grouted up tight, so that the situation never got out of hand.

The Author had mentioned that very large quantities of grout got away and that there had been great losses of air. Mr Glossop thought in that kind of ground such losses must be expected, and individual judgement should be used in dealing with it. It was astonishing how much air did escape from a shaft, and how far it travelled without disturbance to the ground. It might be of interest to mention two cases he had known where air in the Thames Valley had travelled very considerable distances; it had passed through peat beds, lost its oxygen because the peat began to oxidize, then had got into a neighbouring excavation and, being deficient in oxygen, had formed a death trap. At Dagenham five men had been

killed when they went down a shaft; all died before they could be pulled out. There had been another narrow escape in 1939 for the same reason. It was something worth remembering, and could hardly be foreseen by those who had no actual experience of it.

Mr J. A. K. Hamilton, congratulating the Author, said that he had evidently taken a considerable time in choosing the method of doing the job, because it would be noticed that the contract had been let two years before work was started on the site itself and, presumably, most of that time had been spent in investigating actual site conditions and the ground.

The excavation necessary to place the precast segments had obviously been very difficult. The Author's photographs had shown some very large vertical faces, and candidly Mr Hamilton did not like them, though probably they could not have been avoided. The large vertical faces in running ground with boulders, adjacent to a large building such as the K.P.M. building and a main roadway, must have caused the Author some sleepless nights, with the ground moving and water pouring in. The Author made only one reference to poling; that was at the special base of cylinder E15, but presumably in many cases to stem the flow of the ground and water he used poling and other precautions not mentioned in the Paper.

The decision to underpin the old cylinders was interesting, and had apparently been justified by the results; but, generally speaking, it was a good deal more difficult to underpin than to sink cylinders in that type of ground; it would be interesting to know whether, in the case of the nine old cylinders which had been left at distances ranging from 2 to 16 feet in the old beach formation, and the three new ones, consideration had been given to sinking instead of underpinning them. Probably the Author would say that the presence of boulders in the ground, together with old piles, had been the deciding factor; or it might have been the results achieved by the previous contractor. The Author did not say much about how that contractor had sunk those cylinders into their position and condition; some information about that might be illuminating. Cylinder B3, at any rate, had started on its own initiative and had to be stopped; so that it would appear that there could have been some possibility of sinking those cylinders, and not underpinning them.

It would also be interesting to know whether any bores were made in the bottom of the cylinders immediately prior to concreting, whether the Author test-loaded any of the cylinders prior to concreting the raft at the top, and whether he had obtained any settlement figures on individual cylinders from test-loading.

The work on cylinders E12 and E15 had been done under compressed air, and two air-locks had been used. Had there been any particular reason for using two air-locks at once, or was it a matter of delivery of plant? Mr Hamilton did not know why two cylinders fairly close together should be sunk at the same time under air. As Mr Glossop had said, it

was always a difficult matter to restrain air, and with underpinning it was twice as difficult as with sinking cylinders. If there were two adjacent cylinders to be sunk under air, it was not the general practice, in Mr Hamilton's experience, to sink them both at once. He had sunk a number of bridge cylinders side by side, but had never sunk two adjacent at the same time.

He noticed that the low-pressure air had been obtained from a compressor rated at 1,800 cubic feet, driven by a 185-brake-horse-power electric motor. The ground had certainly been very bad, but, even so, that would appear to be a very big consumption of air. The Author, however, had almost answered the question already; apparently it had been necessary, because he had lost the air pressure altogether on occasion. Mr Hamilton had been going to ask him whether he really did use the whole capacity of the motor when dealing with the cylinders in compressed air, because even in bad ground he thought that if a small vertical face was taken out at a time and the leaks were stopped by plugging of some sort, it should have been possible to reduce materially the horse-power consumption. He did not know whether rolling-drum rotary compressors were invariably oily, but that was the case so far as Mr Hamilton had had any experience of them, and the air was very much worse than that obtained from a piston compressor.

There was one small question which he wished to ask in conclusion. It had probably something to do with conditions in the East, about which he knew nothing, but why did the Author consider it necessary to take the low-pressure air pipe nearly down to the bottom of the cylinder?

Mr G. E. Wild said the Paper was very interesting about a job with certain very special characteristics in Singapore, although perhaps it would not have occasioned quite so much trouble in Great Britain. The ground conditions at the site had been most unfortunate; beneath the fill and the geologically recent beach deposits there had been tropically weathered, triassic sandstone-shale formation, which was now known to extend to at least 95 feet below ground level, and which might go down for another 50, or even 100 feet. The results of tropical weathering were, of course, most impressive. That formation had become nothing but a series of large sandstone boulders, more or less decomposed, set in a matrix of multi-coloured stiff clay, which softened very readily in contact with water. Above that, the beach deposits consisted of very soft black organic silt with many shell fragments and a mass of sponge-like corals. In some places he had been told that hard coral had been found, but he had seen none, and he wondered whether in fact in the subsequent work the Author had found any hard coral.

The job had been another very striking testimony to the paramount necessity of carrying out a thorough and adequate site investigation before the job rather than afterwards. Mr Hamilton had remarked on the two years which had elapsed between the signing of the contract and starting

work on the site, and had wondered whether that had been devoted to site investigation. It had not; if it had been, the designers might well have embarked on an entirely different sort of foundation. Mr Wild thought that perhaps a deep basement-raft could have been constructed at considerably less cost than the cylinders which had, in fact, been used. After all, £300,000 (which was what he made the cost to be) for the foundation of a building 100-foot square in plan was a great deal of money.

A site investigation had been carried out beforehand, and those responsible had found out accurately all about the soft ground, but, having got to rock, there had been no diamond drill available, and it had not been thought necessary to bring one out specially. Mr Wild knew that the consulting engineer had wished to proceed very cautiously and sink a trial cylinder, but he believed that the building owners had forced the pace, and the contract had in fact been let on the basis of a cylinder foundation before it had been proved suitable for the site.

Mr Wild had been associated with the work in June 1951, when about 16 cylinders had been sunk to various levels by the contractor who had preceded the Author's firm on the site. At that stage, of course, the project had been committed to cylinder foundations if they were in any way practicable, but there was very considerable concern at the subsidences which had been taking place round the site, as well as at the failure to find the promised sandstone foundation. He thought that that answered a point which Mr Hamilton had raised. At that time the cylinders were being sunk as monoliths by hand excavation under the cutting edge, and the water was being pumped from under the bottom of the cylinders. The Author had illustrated the type of ground below the beach deposit, the big boulders in a matrix of clay, and *Fig. 6* in the Paper showed a crumpled cutting edge and large boulders jutting out. The Chinese contractor had only hand tools, and the big boulders were just being pulled out. If the cylinder went with a rush it took the boulder down itself, with the result that behind the cylinder walls there were very large voids, and the soft ground from above ran down to the bottom. It was not surprising that the Author should later have found very big voids in the ground above, which he had had to attempt to fill up with grout. It had definitely not been a place for sinking cylinders as monoliths.

In the Paper the Author repeated an opinion which Mr Wild had heard expressed at the time, that if only the water had been got down and kept down, the runs from the beach deposit would have stopped. Whilst that would certainly have reduced them, he was sure that it could not possibly have stopped them altogether. In that sort of ground it was not possible to get the water uniformly low, and to provide adequate filters against loss of ground with the run of the water. The situation was helped, of course, by the effect of the corals, and, where they existed, they were certainly of assistance, but it was not possible to guarantee that they would occur in all the places where they would be needed. The use of

compressed air had therefore been adopted initially after restarting work for sinking through the beach deposits to avoid that loss of ground. He noticed that cylinders E12 and E15 had been sunk in that manner, but between E12 and E15 there were two cylinders, E13 and E14; which had been sunk in free air, and he thought that the Author and the Author's firm might congratulate themselves on being a little fortunate in doing that without any obvious subsidence.

It would be of interest if the Author could give the approximate total quantity of water which they had been pumping at that stage, and whether in fact they did get any considerable runs of material.

The concrete segments, which had been designed and made on the spot, appeared to have been very well suited to their job, but Mr Wild thought that it would have been very much better had they been provided from the start with proper packing and grummets, and possibly with more grout holes, so that they could have been grouted more effectively. The Author had stated that a good deal of grout had been lost initially through the joints, and they had in consequence been unable to stop the water. Mr Wild felt that the whole essence of the scheme was to grout very well to ensure that the water was stopped, because water in a clayey foundation of that kind was an abomination.

The Author also referred to grouting under a cylinder base in order to prestress the clay. Mr Wild gathered that under the cylinder base the Author put first of all a certain thickness of large stones, topped with broken aggregate and a little sand, and when the cylinder had been completed, that had been grouted up. Mr Wild was not quite sure what the Author had had in mind in using the word "prestressing," but leaving water in contact with the clay under the base would allow the clay to soften, and although the subsequent grouting might fill all the remaining voids in the stones and prevent any more movement of the clay into them, there would still be the normal consolidation of the softened clay under the load. No amount of grouting would stop that.

With regard to the reassessment and redesign of the foundations to suit the actual ground conditions, it had been a relatively simple matter to arrive at the safe bearing pressure for the cylinders, but it had been most difficult to obtain samples which could be tested, because there had been so many little fragments of sandstone in the clay. It had been basically a matter, however, of determining shear strength, and obviously it had had to be treated as clay. A much more difficult problem had been that of settlement, and everything depended on whether the 100 feet below the cylinder bottoms was going to act mainly as clay or mainly as sandstone. It had been for that purpose that the four diamond-drill holes had been put down by a local firm to about 60 feet penetration. It had been hoped that it would have been possible to recover a large percentage of core so that an accurate assessment could have been made of the proportions of clay and sandstone, but, of course, those conditions of alternating sand-

stone and clay were very difficult to bore in. It was necessary to have a very experienced operator and large-size drilling equipment, with special core barrels to recover cores of the soft ground. In fact they obtained about 50 per cent recovery, of which about 50 per cent was clay and 50 per cent sandstone, and it had been reasonable to assume that that proportion could be taken for the general 100-foot depth.

On that assumption, and assuming that the clay was evenly distributed throughout the whole of the 100 feet, the settlements had been calculated under each cylinder, assuming that they were all independent, and it had been found that the maximum settlement was about $3\frac{1}{4}$ inches, and that the differential settlement between the maximum and minimum would be about 1 inch. The settlements had also been calculated by the alternative method of assuming that the cylinders had, at about 15 feet below their bases, the same effect as a flexible raft; that had been where the larger figure quoted by the Author, of about 1·9 inch, came from; that would have been the differential settlement between the centre and corners of a flexible raft. The raft which topped the cylinders was in fact of very considerable stiffness, so that the differential settlement likely to arise would be very much less.

Finally, he would like to ask the Author whether, in his experience on the site, he had discovered anything which would have prevented a deep raft foundation being built, had it been desired to do so. Would it in fact have been possible to drive steel sheet-piles down through the beach deposit and into the 10 feet or so of clay which occurred before reaching any serious sandstone, and to excavate a large hole in that protection?

Mr D. H. Little observed that what surprised him was that the soil conditions in a large city such as Singapore should not have been better known by now than they appeared to be from the Paper. The penetrometer described sounded very much like the vane instrument which had first been used with great success, he believed, in Holland, where there was a fairly consistent soft clay at very considerable depth. When he had first seen that at the Second International Soil Mechanics Conference at Rotterdam about five years previously, the general opinion of British soil engineers had been that it would only be suitable in a material in which it had been used a number of times; that was, it was necessary to have plenty of practical experience of the instrument in order to interpret the results. He believed that that instrument, or similar instruments, were being used in Great Britain at the present time on alluvial deposits at estuaries, where again the soil was fairly consistent in its quality. For the site under discussion, however, it would seem to have been quite unsuitable.

Reference had been made to the shear-strength and consolidation characteristics of the clay. It would be interesting to know whether it was a natural clay, and whether it was really a true clay and not a laterite.

If it was a laterite, had it been considered that normal clay techniques were applicable to it?

The calculated differential settlement had been given as between 1 inch and 1·9 inch. Did that mean that the minimum was 0 and the maximum 1 or 1·9 inch? Mr Wild had suggested that the maximum was likely to be 3½ inches, and the minimum, presumably, would be 2½ inches. Had any special precautions been taken in the superstructure to deal with that overall movement and with the differential movement?

Fig. 2 in the Paper seemed to show that the site was at least 300 feet from the sea, and Mr Little would not have thought that the water level would be much affected by the tide. The Author stated that a variation of only 3 feet in the water-table resulted from rain or tide. Had any definite measurements been taken to establish the relationship between tide and water level? The deepest cylinder appeared to have been 40 feet below high water. It would be interesting to know whether any of the water at any time was salt, or whether it had always been fresh.

Reference had already been made to the cost. It would appear that the first contract amounted to $460,000 (Straits), which was about £50,000, whilst the second contract, which had presumably been carried out to put the first one right, cost more than $2,000,000 (Straits), which was about £250,000. The building was of 10,000 square feet, so that it worked out at £30 per square foot for the foundations. Mr Little did not know whether £1 per square foot for foundations would be a proper figure to take, or whether it should perhaps be £2, but he would have thought that £20,000 would have been quite enough for the foundations. A cylinder basically was simply a large-diameter column, and a pile was a small-diameter column. Because there were big loads on a cylinder, cylinders had to be spaced at wide centres, and the raft and superstructure became correspondingly heavy to bridge those big spans. In jetty work, therefore, it was almost always better to use piles at close centres rather than cylinders, and he felt that the Asia building was no exception. The Author said that it was not possible to drive concrete piles, and perhaps they could not be driven far into a clay or material like clay with a shear strength of 3,000 lb. per square foot; but Mr Little would suggest that there was no need to penetrate very far into such a strong soil. If concrete piles could not be driven, had consideration ever been given to the use of steel piles? Steel joists might have been driven down at 5-foot centres, and if a pile hit a boulder, it could be moved slightly aside. Such piles could be capped with a slab about 2 feet thick, and even if the centres proved to be closer than 5 feet, the total foundation cost must have been far less than £250,000.

*** Mr H. J. B. Harding observed that Mr Glossop, in his contribution, mentioned the rarity of the use of segmental shafts for founda-

*** This contribution was submitted in writing upon the closure of the oral discussion.—Sec. I.C.E.

tions. In practice that expedient had been chiefly employed by the few consulting engineers who pioneered and specialized in soft ground tunnelling for tube railways and other purposes where cast-iron lining was common-place and readily available; they had made many ingenious uses of that material, not only for tunnels and shafts, but for cellular cofferdams. Its uses in London were not widely known outside that group of engineers.

For instance, the machine chamber for the Bank escalators had been constructed of a series of small diameter cast-iron shafts at intervals, with cast-iron segments spanning as horizontal arches between them; that construction acted both as retaining wall and foundation. The method had been employed in places on Bazalgette's Victoria Embankment, as well as recently at Mile End and Stratford stations on the Central Line extension of London Transport Railways, where that form of construction was used both horizontally and vertically.

Mr Harding quoted other examples. The foundations of Brittanic House in 1922 had to be carried below the tube railway tunnels at Moorgate Station. In that case the foundations had been placed in tunnels constructed at station level in semi-circular form, and lined with cast-iron segments. Afterwards 6-foot diameter cast-iron segmental cylinders were sunk from the basement of the existing building on to those foundations previously installed, and steel columns were erected inside them. That method had been also used for the same purpose on extensions to Peter Robinson's shop building, to carry foundations below the tube tunnels at Oxford Circus tube station; a third case was its adoption as a temporary expedient in erection of the columns supporting the roof of Piccadilly Circus station prior to the excavation of the machine chamber, which was carried out after the roof had been fully completed.

The Author, in reply, said that, as Mr Wild had explained, the 2 years preceding the underpinning operations had been devoted not to investigating the site conditions but to the partial sinking of the cylinders by the previous contractor. The following summarized the approximate dates of the various operations:—

(*a*) First soil investigation (Penetrometer tests and soil sampling by Messrs Ewart & Co. Ltd.)	March 1949.
(*b*) Sinking of three trial cylinders (By Messrs Ewart & Co. Ltd.)	September 1949.
(*c*) Sinking of all cylinders (By Chinese contractor)	January 1950.
(*d*) Site examination (By Messrs Soil Mechanics Ltd.)	June 1951.
(*e*) Second soil investigation (Diamond drilling by Messrs Ewart & Co. Ltd.)	September 1951.

(*f*) Underpinning of cylinders Started: February 1952.
(By Messrs Gammon (Malaya) Ltd.)
Completed: February 1953.

In fairness to the Consulting Engineer and in order to explain a number of anomalies, it was necessary that certain facts be made known. It was not the Author's intention that the following remarks be interpreted as being derogatory in any sense whatsoever.

Mr Steen Sehested, who did not feel that the work as a whole should go to execution without first proving the design, had recommended the owners to sink one trial cylinder. The owners, in their anxiety to hasten the completion of the building, had suggested sinking three cylinders. That work had still been in progress when the owners reversed their policy and awarded the contract to a Chinese firm. The choice of contractor had been unfortunate, for he had had little experience in that type of work. The situation had been aggravated by the disregard, on the part of the contractor, of the clauses of specification relating to the safe conduct of the work. A peculiar situation had arisen wherein the power of the Consulting Engineer to control the contractor was in name only.

The large vertical faces at the bottom of the cylinder referred to by Mr Hamilton had existed before the Author's firm had started underpinning operations. That was one of the main reasons why so much trouble had been experienced during the sinking of the cylinders. The loss of ground was largely attributable to a tendency of the Chinese contractor, when meeting sandstone boulders or coral, to undercut the edge of the cylinder for several feet. The Author understood that during the sinking of the cylinders very little inrush of soil had occurred when the cutting edge was near the bottom of the excavation, and it had been the invariable experience that large soil inrushes stopped when the excavation was filled to the cutting edge.

The Author agreed with Mr Hamilton that the conditions shown in *Fig. 6*, facing p. 418, were rather alarming, and when the Author's firm had underpinned the cylinders they had never excavated more than about 18 inches below the cutting edge; that had given sufficient clearance to insert one segmental ring.

Only one reference had been made to poling because that had been the worst case. There had been other similar cases but they had been neither serious nor numerous. A great deal depended on the effectiveness of the grout keeping the ground behind cylinders tight. If that object was not achieved then the ground was more liable to collapse when undercutting behind the segments. The Author said he could quote a number of cases where between 100 and 200 bags of cement had been used for back-grouting only two or three rings, without any sign of having reached saturation point. Apart from poling, gunny sacks and clay had sometimes been packed behind the segmental rings for stemming the flow of ground and water. That method had been adopted for less serious cases.

The Author said that when his firm had been awarded the contract for underpinning the cylinders there had been no reference in the specification suggesting that another attempt might be made to sink any of the cylinders. The decision to underpin the cylinders had been the result of consultations held between the owners and the Municipality of Singapore together with their respective consultants. No further sinking of the cylinders had been contemplated owing to the alarming situation which had developed during the subsidence of the ground. Furthermore, underpinning of the cylinders had been considered by the Municipality to be the most acceptable method of continuing the work without jeopardizing the safety of the buildings in the vicinity. The Author wished to point out, however, that Mr Steen Sehested had been of the firm opinion that with controlled water-keeping and reasonable care the cylinders could have been sunk to the bottom formation without appreciable loss of ground and subsequent danger.

The Author regretted that he was unable to give further information about the sinking of the cylinders, but as he had pointed out in the Paper, that work had been carried out by another contractor and the records were not available. A comprehensive report on that work would have been interesting.

Apart from the four deep bores in cylinders A1, A4, B2, and E5, no further bores had been made at the bottom of the cylinders on reaching formation level. It had been felt that the results of the second soil investigation had yielded sufficient information to make it unnecessary to explore the subsoil further.

The settlement of the cylinders under test load prior to concreting the raft would have proved interesting but unfortunately the contract had not asked for such tests. The Author's opinion was that a number of such tests should have been carried out.

With regard to the close proximity of the two air-locks on cylinders E12 and E15, the Author pointed out that those two cylinders had been selected because they represented the worst cases. In actual fact the air-lock over cylinder E15 was not put into operation until the work in E12 was fairly advanced.

He agreed that the air compressor was large, or at any rate he had thought so when making comparisons with plant used in Great Britain for similar purposes, but when they began to experience the air losses to which he had referred earlier, he had been glad that the compressor was so large. There had been instances when the loss in pressure was so severe that it had been impossible to carry on with the work until the leaks had been stopped. With both air-locks in use it had been necessary to operate the compressor at full capacity.

It had been known that a substantial volume of air escaped through the joints in the segmental lining, and the Author agreed with Mr Wild that the concrete segments should have been provided from the start with proper packing and grummets. The difficulties encountered as the

result of leaks mentioned on p. 433 would have been considerably minimized.

The Author admitted that there had been a good deal of oil in the low-pressure air entering the air-lock, proving quite a nuisance at times. That excess oil had been partly the result of difficulties experienced with the compressor during the early state of the work when one of the radial blades had seized in the rotor and, to avoid a similar occurrence, the quantity of lubricating oil had been increased. Reference to the introduction of oil removers was made on p. 442.

Mr Hamilton had asked why the low-pressure pipe had been taken down to the bottom of the cylinder. Originally the outlet end of the pipe had been located near the top of the cylinder and it had been found that the cool air escaped through the relief valve in the side of the air-lock without ventilating the bottom of the shaft. The working section of the cylinder had become extremely hot and sticky, producing unbearable working conditions. The deeper the cylinder the worse the conditions. Undoubtedly in the original scheme the cool air had tended to float to the bottom of the shaft but it had been overpowered by the hot and humid rising air, which very effectively reversed the cycle of operation of the air-conditioning plant.

Mr Wild had asked if any hard coral had been encountered. It had, but not in very large quantities, and it was not so hard as the sandstone boulders.

With regard to runs of beach in those cases where the shafts had been underpinned in the open, the Author could not say that they had been serious—if they had been, compressed air would have been laid on. What made the work difficult in certain cylinders was the excessive flow of water mentioned on pp. 425 and 433.

He was afraid that no check had been kept on the amount of water pumped out of the cylinders. That would have been quite interesting, but rather a laborious and expensive undertaking if reliable results were to be obtained. One noticeable feature during the construction of the foundations had been the wide variation in the amount of water encountered in individual shafts. In general it had been found that all shafts at the north-west end of the site (the K.P.M. building side) were comparatively "dry," whereas all those on the south-east end (towards Raffles Quay) were very "wet." It should be pointed out, however, that most cylinders on the north-west side were through the beach formation, which was not the case on the south-east side, and that the watertightness of the cylinder walls probably accounted for the comparative dryness of those shafts. Nevertheless, cylinder A1 which had penetrated only 10 feet into the ground was found to be very "dry" throughout its depth.

The Author wished to emphasize his remark in the Paper on the impossibility of keeping the bottom of the excavation even comparatively dry when excavating in the clay. During concreting of the base slabs

of the cylinders, precautions had been taken to ensure that no free water was trapped between the slab and the clay. A pump had been kept running continuously in a central sump thus localizing the accumulation of water. Unfortunately the water, as it gravitated towards the sump, had softened the surface of the clay, forming a slurry of the consistency of a thick cream, an inch or two in thickness. It had been anticipated that as the full weight of the building came to bear on the clay, that thick slurry would be gradually squeezed out from under the cylinder bases, resulting in a settlement of the foundations in excess of that caused by the normal consolidation of the clay. Grout had been injected under the base slabs with a view to introducing stresses similar in magnitude to those which would eventually develop when the full load of the building came to bear on the cylinders. It had been hoped that the grout would partly push out the clay slurry from under the bases and partly stabilize it by combining with it. The Author admitted that the experiment had been speculative, but it had seemed the best they could do under the circumstances. That was what he had meant by "prestressing" and he regretted the misunderstanding created. He agreed with Mr Wild that the normal consolidation of the clay could not be stopped by grouting.

Mr Wild had asked if it would not have been possible to build a deep raft foundation by driving steel sheet-piling round the site. The Author did not think so. In almost every cylinder they had underpinned they found sandstone boulders very close to the top of the clay formation. Driving steel sheet-piles in that type of ground would have proved a very hazardous operation. The boulders they encountered varied considerably in size from 2 or 3 feet to 12 feet or more. The Author remembered a particular case where a boulder extended throughout the bottom of the excavation of cylinder B1. That cylinder had an external diameter of 13 feet 6 inches. That answered Mr Little's query as to whether closely spaced steel joists could not have been driven a short distance into the clay.

The Author agreed that £300,000 was a great deal of money to spend on a foundation of this size, and probably a deep raft foundation could have been built at a much cheaper cost if the problem of boulders could have been overcome.

As Mr Little had suggested, the penetrometer proved unsuitable for the type of ground encountered, but then that could not be known until the subsoil had been explored. Furthermore at that time there had not been a great selection of equipment in Singapore suitable for subsoil exploration or carrying out proper laboratory tests.

Mr Little had asked if the clay was a true clay or a laterite. That was a little difficult to answer because the term "laterite" was often used rather loosely. The Author had encountered both clay and laterite in Malaya, which were distinguishable by their appearance. The weathered triassic shale encountered under the Asia Building was definitely not what

was generally known by the term " laterite " and exhibited all the physical properties of a true clay.

The Author said that so far as he knew, no special precautions had been taken in the superstructure to deal with the overall differential movement of the foundations as the result of the consolidation of the subsoil.

He could give no satisfactory answer to Mr Little's question about the water table, because he had not been personally responsible for the measurements, which had been taken before he had become acquainted with the project. No subsequent systematic observations had been made. So far as he knew no definite relationship had been established between tide and water level. It was probable that high tides affected the water table during heavy rainstorms in so far as they reduced the rate of discharge of surface and ground-water into the monsoon drains and the Singapore River, which discharged out to sea. No analytical tests had been carried out on the ground-water, and the Author could not tell whether it contained any salt. It was not thought advisable to taste it owing to a suspected leaking sewer in the vicinity.

The closing date for Correspondence on the foregoing Paper has now passed without any contribution being received.—SEC. I.C.E.

ELECTION OF ASSOCIATE MEMBERS

The Council at their meetings on the 27th April and the 25th May, 1954, in accordance with By-law 14, declared that the undermentioned had been duly elected as an Associate:

Home

Smeed, Reuben Jacob, Ph.D. (*London*).

and as Associate Members:

Home

Anderson, Albert William, Stud.I.C.E.
Bennett, Colin Joseph, Grad.I.C.E.
Blake, Leslie Spencer, B.Sc.(Eng.) (*London*), Grad.I.C.E.
Brailey, James Alan, B.Sc.(Eng.) (*London*).
Burton, Thomas, B.Sc.(Eng.) (*London*).
Butler, Geoffrey Reginald Charles, B.Sc.(Eng.) (*London*), Grad.I.C.E.
Cartwright, Donald, Grad.I.C.E.
Cope, Michael Donald, B.A. (*Cantab.*), Grad.I.C.E.
Copp, Peter William, B.Sc.(Eng.) (*London*).
Cresswell, Geoffrey Charles, B.Sc. (Eng.) (*London*).
Davies, Joseph Wynne, B.Sc. (*Wales*), Grad.I.C.E.
Diggle, George, B.Sc.(*Durham*).
Don, John Spencer, B.Sc. (*Edinburgh*), Stud.I.C.E.
Eilenberg, Hans Eric, B.Sc.(Eng.) (*London*).
Forster, Alfred Ian, B.Sc. (*Durham*).
Grubb, John McEwan, Grad.I.C.E.
Gudge, Harvey John, B.Sc.(Eng.) (*London*), Grad.I.C.E.
Hall, Douglas Edward, B.Sc.Tech. (*Manchester*), Grad.I.C.E.
Hall, William Roy, Grad.I.C.E.
Hann, Reginald Oliver.
Harrison, Richard Hayton, B.Sc. (*Birmingham*), Stud.I.C.E.
Hawley, Dennis John, B.Sc.(Eng.) (*London*), Stud.I.C.E.
Hipperson, Edwin Paul, B.Sc.(Eng.) (*London*).
Hodge, Peter Alan Rea, B.Sc. (Eng.) (*London*).
Horne, Ronald Arthur, B.Sc.(Eng.) (*London*).
Hutton, Peter Desmond, B.Sc.(Eng.) (*London*), Grad.I.C.E.
King, Joseph Norman, B.Sc.Tech. (*Manchester*).
Kirby, James Barry, B.Sc. (*Birmingham*).
Krarup, Anthony Charles, B.Sc. (Eng.) (*London*), Grad.I.C.E.
Lawrence, Kenneth Roy, B.Sc. (*Bristol*), Grad.I.C.E.
Lloyd, George Francis, B.Sc.(Eng.) (*London*), Grad.I.C.E.
McDonald, Walter, Stud.I.C.E.
Mackey, Robert Douglas, B.Sc. (*Durham*), Stud.I.C.E.
Melrose, John William, B.Sc.(Eng.) (*London*), Grad.I.C.E.
Moir, Douglas Lennox, B.Sc. (*Aberdeen*).
Morris, Christopher John Easton, M.A. (*Cantab.*).
Parkes, John Leslie, Stud.I.C.E.
Peatfield, Derek Edward.
Pettinger, Bryan Ernest, Stud.I.C.E.
Pickersgill, Henry Hewitt, B.Sc. (*Leeds*).
Priest, Herbert, B.Eng. (*Sheffield*), Stud.I.C.E.
Rogers, Samuel Harry, B.Sc.(Eng.) (*London*).
Sandover, John Alexander (*Jun.*), B.Sc.(Eng.) (*London*), Grad.I.C.E.
Shepherd, George Duncan, B.Sc. (*St Andrews*), Stud.I.C.E.
Smith, Dennis Oxley, Stud.I.C.E.
Smyth-Osbourne, Kennet Robert, B.A. (*Cantab.*), Grad.I.C.E.
Stratford, Sidney William Lendon, Stud.I.C.E.
Talbott, George Peter Proctor.
Thomason, Eric, B.Sc.(Eng.) (*London*).
Weddell, Thomas William, B.Sc. (*Durham*), Grad.I.C.E.
Wright, Stanley Gerald.
Young, Ronald, Stud.I.C.E.

Abroad

BHASKARAN, TYAGARAJA, B.Sc. (*Madras*), Grad.I.C.E.
BUNCE, GEORGE KENMIR, B.E. (*New Zealand*).
DOWRICK, BERNARD GEORGE, B.E (*New Zealand*).
DOYLE, LOUIS CRONIN.
GILL, JOHN MARSDEN, B.Sc.Tech. (*Manchester*).
JAMIESON, CHARLES FLEMING, B.E. (*New Zealand*).
KIDDLE, WILFRID KAY.
KINGSLAND, JAMES WILLIAM, B.E. (*New Zealand*).
SPELDEWINDE, FREDERIC CHARLES, Grad.I.C.E.
SYMON, DAVID FRANK, B.E. (*New Zealand*).
THOM, DAVID ALAN, Grad.I.C.E.

DEATHS

It is with deep regret that intimation of the deaths of the following has been received.

Members

HENRY FARRE BOWEN (E. 1906, T. 1920).
EDMUND GRAHAM CLARK, C.B.E., M.C., M.Sc. (E. 1914, T. 1938) (*Secretary*).
JOHN ERNEST CROASDAILE, M.A., B.A.I. (E. 1899, T. 1903).
WILLIAM HUGH GORTON, T.D. (E. 1921).
ARTHUR CYRIL JENNINGS, O.B.E. (E. 1914, T. 1942).
JOHN RICHARD MATTHEW (E. 1917, T. 1945).
REGINALD WILLIAM NEWMAN (E. 1893, T. 1912).
GEOFFREY PARKER (E. 1906, T. 1928).
NEIL JAMES PETERS (E. 1900, T. 1921)
Sir ARTHUR WATSON, C.B.E., LL.D. (E. 1899, T. 1911).

Associate Members

EDWARD ANDREWES, B.Sc. (E. 1905).
GEORGE MAURICE BEAUMONT (E. 1944).
ROBERT BONNER (E. 1911).
JAMES THOMAS HAROLD RICHARD HUGH LEDICOTTE BURRELL (E. 1904).
ALBERT CROAD (E. 1912)
DENNIS CUTTIFORD (E. 1943).
GEORGE MCLEAN GIBSON, O.B.E. (E. 1931).
JOHN VICKERS HALL, O.B.E., T.D. (Lt.-Col.) (E. 1927).
LESLIE MARK HOWARD (E. 1928).
EDWARD ROBERT KENDRICK (E. 1914).
ROGER FERDINAND VOGEL LEECH (E. 1913).
ELWYN LAURENCE MACLEOD (E. 1946).
ARTHUR GEORGE MANSELL (E. 1926).
JOHN EDWIN WALDEN MOORE (E. 1950).
ERNST JULIUS OELSNER, D.Eng. (E. 1949).
Sir JOHN OWEN SANDERS, C.M.G. (E. 1921).
VERNON CHARLES SMITH (E. 1910).
CHARLES VIVIAN STEPHENS (E. 1917).
LEONARD GODFREY PINNEY THRING, M.A. (E. 1898).
HERBERT GEORGE TISDALL, B.Sc.(Eng.) (E. 1909).
ROBERT HENRY RAWLINSON WALKER, M.A. (E. 1939).
HENRY NORMAN WILFORD (E. 1927).

Students

HENRY FINDLAY BAIRD (A. 1952).
DOUGLAS GORDON MCKINSTRY (A. 1946).
MAURICE SIDNEY SPINKS (A. 1949).

REPORT OF THE COUNCIL AND STATEMENT OF ACCOUNTS 1953–54 *

In accordance with the By-laws, the Council present the following report on the state of the Institution.

Meetings.—Nine Ordinary, one Supplementary, and twenty-four Divisional Meetings have been held as compared with a total of thirty-six in Session 1952–53. Two of the Meetings were held on successive evenings, the 25th and 26th May (one being held jointly with the Institution of Electrical Engineers) when companion Papers on the hydro-electric development work at Owen Falls, Uganda, were presented for discussion. Members of the Institution were invited to a meeting at the Institution of Electrical Engineers on the following evening, 27th May, when a third Paper on the development and utilization of hydro-electric work in Uganda was discussed.

A list of the Papers and Lectures presented at the Ordinary and Divisional meetings will be found in Appendix I.

The Opening Meeting of Session 1953–54 took place on the 3rd November, when Mr W. P. Shepherd-Barron, in his Presidential Address, dealt with the docks of London. He referred briefly to the early development of the first riverside wharfs and then showed in detail how the growth of ships, gradual at first but later becoming more pronounced, had required the development of an extensive system of impounded docks. He traced the history of the amalgamations of various dock companies and explained the circumstances in which they were finally combined by Act of Parliament in 1909 into the Port of London Authority. After giving detailed information regarding the civil engineering work involved in the building of the larger docks constructed during the past 100 years, and of the twentieth century extensions, the President gave a brief analysis of the manner in which the size and growth of shipping would affect the design of future works.

Awards for Papers.—The awards for Papers presented at Ordinary and Divisional Meetings in Session 1953–54 will be announced at the Opening Meeting next Session, and the awards for Papers printed in the Proceedings with written discussion only, between January and December 1953, will be announced at the Annual General Meeting on the 8th June.

Conferences.—*Conference on the North Sea Floods of* 31 *January*/1 *February*, 1953. The Council arranged a two-day Conference to discuss the engineering aspects of the disastrous floods which occurred on the coasts bordering the North Sea following the storm surge of the 31st

* Presented to the Annual General Meeting, 8 June, 1954. An account of that meeting is printed as an inset with this number of Part I of the Proceedings.—SEC. I.C.E.

January, 1953. The Conference was held in the Institution on the 16th and 17th December and aroused much interest. A number of eminent Dutch and Belgian engineers were present and took part in the discussions. The proceedings of this Conference have been published in book form.

The following twelve Papers were presented :—

"A General Survey of the Damage Done and Action Taken," by J. V. Spalding, B.A., M.I.C.E.

"Storm Surges on the East Coast of England," by Commander W. I. Farquharson, F.R.I.C.S., R.N.(Ret.).

"Some Meteorological Aspects of the North Sea Floods with Special Reference to February 1953," by S. P. Peters, B.Sc.

"Soil Mechanics Studies of Failures in the Sea Defence Banks of Essex and Kent," by L. F. Cooling, D.Sc., and Arthur Marsland, M.Sc., Grad.I.C.E.

"Design of Sea Defence Works in relation to Height of Tide and Degree of Exposure," by C. H. Dobbie, B.Sc.(Eng.), M.I.C.E.

"The Incidence of Storm Surges as a Factor in the Design of Coast Protection Works," by Jack Duvivier, B.Sc.(Eng.), M.I.C.E.

"Sea Defence Works on a Sandy Eroding Coast with Scanty Littoral Drift," by S. W. Mobbs.

"Damage to the Kent Coastline, and Restoration Works," by E. L. Snell, O.B.E., A.M.I.C.E.

"Sea Defences in the Wash and Estuary of the Great Ouse in relation to the Tidal Surge of the 31st January, 1953," by W. E. Doran, O.B.E., B.A., B.A.I., M.I.C.E.

"Flood Damage in Norfolk and Suffolk," by K. E. Cotton, M.B.E.

"Damage and Remedial Operations on the Lincolnshire Coast," by F. H. Tomes, O.B.E., M.I.C.E.

Conference on Welded Structures.—A Conference organized jointly by the Institution, the Ministry of Works, and the Institution of Structural Engineers was held at the Institution from the 23rd to 26th November, 1953. The following is a list of Papers presented for discussion at the Conference :—

"The Design of Welded Steel Frames for Multi-storey Buildings," by W. A. Mitchell, M.I.Struct.E., M.Inst.W.

"Problems of Fabrication and Erection in All-Welded Multi-storey Framed Buildings," by D. C. C. Dixon, B.A., A.M.I.C.E.

"General Review of Welding in Shipbuilding," by F. C. Cocks, B.Sc., M.I.N.A., M.Inst.W.

"Welded Dock Gates," by F. J. Walker, A.M.I.C.E.

"Welding in Caissons," by F. W. Sully, M.I.C.E.

"Oil and Gas Storage Vessels," by M. Noone, M.I.Mech.E.

"Design of Single-Storey Framed Buildings and Portal Frames," by W. S. Atkins, B.Sc., M.I.C.E., M.Inst.W.

"Fabrication and Erection of Single-storey Framed Buildings and Portal Frames," by R. W. Schofield, M.I.Struct.E., M.Inst.W.
"Design Fabrication and Erection of Braced Roof Structures," by S. M. Reisser, B.Sc., A.M.I.C.E., M.I.Struct.E.
"Plate Girder Bridges," by G. Roberts, B.Sc., M.I.C.E., and O. A. Kerensky, B.Sc., M.I.C.E.
"Design, Fabrication, and Erection of Trussed Girder Bridges," by E. M. Lewis, A.C.G.I.
"Welded Tubular Structures," by T. Bedford, M.I.C.E., M.I.Struct.E., M.I.Mech.E.

The attendance at the Conference was 340, and there were 142 participants in the discussions.

The Proceedings of the Conference will be published by H.M. Stationery Office.

Conference on Engineering Education.—Following on the Conference on Engineering Education and Training, which was held in London in January 1953, and which was attended by representatives of the engineering societies of Western Europe and the U.S.A. (EUSEC), a second Conference is to be held in Zurich in September and a meeting of the Organizing Committee was held in Brussels in March 1954.

Publications—It may be of interest to members to learn that the following are the circulation figures for the "running" publications:—

Proceedings

Part I,	published	6 times a year	—21,000 copies	of each	number
,, II,	,,	3 ,, ,,	— 7,200 ,,	,, ,,	,,
,, III,	,,	3 ,, ,,	— 8,000 ,,	,, ,,	,,

Géotechnique, issued 4 times a year—1,000 copies of each number.

Railway Engineering Abstracts, issued monthly—1,220 copies of each number.

The following have also been published during the year:—

Supplement to the Bibliography on Soil Mechanics covering the year 1952.
Supplement to the Bibliography on Prestressed Concrete covering the year 1952.
Civil Engineering Code of Practice No. 4: Foundations (1954) (on behalf of the Civil Engineering Codes of Practice Joint Committee).

Engineering Divisions.—The new Hydraulics Engineering Division has completed a programme of three meetings in the current Session dealing with water resources of the Nile, rainfall and run-off at Elan and Claerwen, and land drainage in England and Wales. The remaining seven Divisions

held twenty-one meetings and visits were made to a number of engineering works.

Library.—The reorganization of the main library has now been completed and the reclassification and rearrangement of the books in the upper library, which contains the bound copies of journals and proceedings of various societies, is in progress.

To help members in their use of the library a study corner has been established at the east end of the library which has been furnished with four special desks.

Bookings for the loan of films in the film library have totalled 187, and there has been an increase in the number of members availing themselves of the service providing for the loan of lantern slides. One new film and several slides have been added to the library during the year, and a revised catalogue of the films and slides has been published.

Considerable progress has been made in the formation of the collection of postage stamps depicting civil engineering works. A selection of the stamps is always on view in the library, and the whole collection can be seen by members on request.

During the year 590 volumes were presented to the Library and 435 were purchased, making a total on the 31st March of 68,763 volumes and 18,718 pamphlets. 3,841 applications for the loan of books were dealt with.

Local Associations.—During the year under review the Local Associations have continued their activities; brief accounts of these appear in Appendix II.

There have been some changes among the Honorary Secretaries. Mr H. M. Nelson has acted as Honorary Secretary of the Glasgow & West of Scotland Association during the absence, through illness, of Dr C. M. Moir. In the Southern Association Mr Ian Wilson succeeded Mr R. A. J. Cork, and Mr T. H. Aspey took over from Mr J. T. Firth (North Western). In the recently formed Hull & East Riding Branch of the Yorkshire Association, Mr H. S. Waddington succeeded Mr D. E. Glover as Branch Honorary Secretary.

Awards made by the Council for Graduates' and Students' Papers presented before Local Associations in Session 1952–53 included Miller prizes to two Graduate Members and two Student Members of the Edinburgh & East of Scotland Association; to a Graduate Member of the Northern Ireland Association; to a Student in the South-Western Association; and to a Student in the South Wales & Monmouthshire Association.

The Dugald Clerk Lecture "Plant for the Construction and Maintenance of Highways," which had been delivered by Mr R. R. W. Grigson to the Association of London Graduates and Students, was repeated before the Northern Counties; North-Western; South Wales & Monmouthshire; and the Midlands Associations.

Overseas Associations.—The Malayan Association continued its activities under the Chairmanship of Mr G. M. Wheat who succeeded Mr H. M. Alexander. The Honorary Secretary has been Mr A. D. Eaton; Mr J. H. C. Shakespear continued as Honorary Treasurer. The future of the Association in relation to the Singapore/Malayan Joint Overseas Group continues to be under consideration locally.

The Chairman of the Victorian Association has been Mr T. W. Carey and Mr F. W. Green has acted as Honorary Secretary and Treasurer. The membership of the Association reached a total of 151 during the year and is greater than it was last year.

During the Session, with the approval and support of the Victorian Association, an informal group of members resident in Tasmania has been formed to hold regular meetings. It is not intended that the group should be a sub-Association with constitution and rules, nor that it should compete in any way with the Tasmanian Division of the Institution of Engineers of Australia. It is intended merely to hold periodical informal meetings for the discussion of engineering subjects and to assist younger engineers and students. Mr R. M. H. Garvie is the Chairman of the informal committee; Colonel R. A. Milledge the Honorary Secretary, and Mr J. A. Watts is the third member.

The Trinidad Branch of the West Indies Association formed, during the year, a Students' Section whose first meeting was held in November 1953.

The Annual Dinner of the Branch was, according to custom, held jointly with the local Branches of the Institutions of Mechanical and Electrical Engineers on the 7th November, 1953. His Excellency the Governor, Sir Hubert Rance, G.C.M.G., G.B.E., C.B., and Lady Rance were the principal guests.

During the year four visits and a film show were held jointly with the local Branches of the Institutions of Mechanical and Electrical Engineers.

Mr D. D. Ash (Member of Council) continued as Chairman, and Mr C. Dupenois as Honorary Secretary.

Joint Overseas Groups.—The Abadan Joint Overseas Group was formally dissolved during the Session.

The Argentine Joint Overseas Group continued under the Chairmanship of Mr W. R. Webb, A.M.I.Mech.E., with Mr J. H. Robinson, A.M.I.Mech.E., as Honorary Secretary.

The first session of the Hong Kong Joint Overseas Group commenced on the 1st May, 1953, and several meetings were held at which Papers presented at the parent Institutions were discussed. The Chairman of the Joint Group has been Mr S. E. Faber, A.F.C., B.Sc.(Eng.), M.I.C.E., while Mr J. J. Robson, A.M.I.C.E., has acted as Honorary Secretary.

The formation of three new Joint Overseas Groups—Singapore/Malayan; West Africa; and Iraq and Persian Gulf—was approved by the Council during the year, in conjunction with the Institutions of Mechanical and Electrical Engineers.

The Singapore/Malayan Group held its inaugural meeting in October 1953 and Mr R. J. Hollis-Bee, M.I.C.E., has been Chairman and Mr W. Trafford, M.B.E., A.M.I.E.E., Honorary Secretary. Two Papers and several visits to works were arranged. The activities of the Group are at present confined to the Colony of Singapore, but this question continues to be under consideration.

The West African Joint Group held its first General Meeting at Lagos in September 1953. The Chairman of the Interim Committee has been Mr Alexander McDonald, B.Sc., M.I.C.E., and the Honorary Secretary, Mr E. J. Evans, M.Sc., A.M.I.C.E. Three Papers and four visits to works were arranged and the formation of a sub-committee to arrange meetings at Accra was approved.

The formation of the Iraq and Persian Gulf Joint Group was approved in September 1953 under an interim Committee with Mr R. C. Kelt, M.B.E., B.Sc., M.I.C.E., as Chairman and Mr J. J. Gandy, A.M.I.C.E., as Honorary Secretary.

The Association of London Graduates and Students.—The Opening Meeting was held on the 4th November, when the Chairman of the Association, Mr P. C. Marley, Grad.I.C.E., gave an address on "Some Expedients adopted in Foundation Construction," the President taking the Chair.

The Dugald Clerk Lecture, 1954, on "Plant for the Construction and Maintenance of Highways," was delivered by Mr R. R. W. Grigson, T.D., B.Sc.(Eng.), M.I.C.E., on the 6th January.

A meeting was held for the reading and discussion of a Student's Paper, and two meetings were held at which informal addresses were delivered by invited speakers, and the subjects of "The Aesthetics of Engineering" and "Timber as a Structural Material," provoked a lively interest. A joint meeting, with the Graduate and Student sections of the Institutions of Mechanical and Electrical Engineers, took place on the 18th March, when Sir Christopher Hinton, M.A., M.I.Mech.E., presented a Paper on "Atomic Energy Made Easy."

Six visits to works were arranged during the Session, in addition to the inspection of the work in progress on the underpinning of the south wall of the Institution, for which facilities were granted for more than 70 Graduates and Students to visit the site during lunch-times for several weeks. A visit to the Atomic Energy Research Establishment created much interest and the number of applications received was double the permitted size of the party.

Social events included a Smoking Concert following the Chairman's

Address, and a Joint Dance with the Graduate and Student sections of the Institutions of Mechanical and Electrical Engineers.

Competition for the Institution Medal and Premium (London University).—The Competition for the Institution Medal (London University) took place on the 15th May, 1953. The President, Mr H. F. Cronin, took the Chair at the meeting which was attended by 121 students and graduates. The following Papers were presented :—

"The Enlargement of Tube Tunnels, with Examples Taken from London's Underground Railways," by J. A. Bergg, Stud.I.C.E. (Queen Mary College).

"The Structural Development of the Bridge," by C. B. Brown (King's College).

"A Review of Site Consolidation and Drainage by Ground-Water Lowering and Other Methods," by J. G. Measor, Stud.I.C.E. (City & Guilds College).

"Excavation and Treatment of Aggregates for Use in the Production of High-Grade Concrete," by F. J. Watson, Stud.I.C.E. (University College).

The three judges were Colonel G. T. Bennett, Mr Ralph Freeman, and Mr R. Glossop, who, after expressing their appreciation of the high standard of the four Papers submitted and the manner in which they were presented by the Authors, awarded the Medal and Premium to Mr J. G. Measor (City & Guilds). They also recommended that a Commendable Mention and Premium of £5 be awarded to Mr J. A. Bergg (Queen Mary College).

Competition for the Institution Medal and Premium (Local Associations).—Owing to lack of sufficient entries for the Competition for the Institution Medal and Premium (Local Associations) the Council regretfully decided that the Competition could not be held this year.

Examinations.—The number of candidates who applied through the Institution and attended the Common Preliminary Examination conducted by the Engineering Joint Examination Board was 93 for the October 1953 Examination and 113 for the April 1954 Examination.

The number of candidates examined in the October 1953 Institution Examination (Parts I and II) was 454 including 80 at 21 centres overseas. For the April 1954 Examination there were 600 candidates including 101 at 15 centres overseas. In October 1953, and April 1954, 872 candidates were interviewed for the Professional interview including 225 at 26 centres overseas.

Bayliss Prize.—For the April 1953 Examination the Bayliss Prize was awarded to Mr W. J. Chodzko-Zajko, Stud.I.C.E., of London, and that for the October 1953 Examination to Mr C. G. McMillan, Stud.I.C.E., of New Zealand.

Research.—No new committees have been appointed during the year and, whilst some committees will soon have completed their tasks, none has been dissolved. The following is a summary of the work of the Research Committee :—

Abstracting.—After considering both past and present abstracting services this sub-committee concluded that it would be preferable to produce a single publication of abstracts covering the whole field of civil engineering rather than to produce separate abstracts covering various aspects. To obtain some measure of the demand for such a publication a questionnaire was sent to 1,000 corporate members, selected at random. The replies are being analysed.

Coast Protection.—The East Coast floods of 1953 drew attention to a number of problems and the Committee is preparing a report on research work, the need for which has been emphasized by the floods.

Compressed Air.—The Ministry of Labour and National Service now propose to publish the regulations on compressed air and diving as a separate document instead of waiting until agreement is reached between the parties concerned on the regulations on all aspects of works of civil engineering construction.

Erosion of Earthen Banks.—Following the East Coast floods of 1953, it was felt that the conclusions so far reached by the Committee might be useful to engineers engaged on reinstatement work. Consequently, an interim report was produced and copies placed in both the lending and reference sections of the Library.

Hydraulics.—Progress has been made by the sub-committees appointed to prepare reviews of recent developments in various branches of hydraulics and it is hoped to publish their work during 1954.

Location of Underground Services.—Comments received on the 1946 Report have been taken into consideration in the preparation of a revised draft report. This is now being considered in detail and a new report should be available in the year 1954/5.

Mechanical Properties of Aggregates.—A review of the methods of testing aggregates for structures other than roads will shortly be ready for publication.

Mining Subsidence.—The Committee has considered various reports on the subject and has discussed how research might help to ameliorate the effects of subsidence. Recommendations for research are to be formulated.

Performance of Concrete-Mixing Machinery.—Performance tests developed at the Road Research Laboratory have been considered by the Committee, which is of the opinion that these tests are of greatest use to the manufacturer and that further work should primarily be directed to assisting the designer to produce a more efficient machine.

Pile-Driving.—Consideration is being given to data contained in the

three reports which were received in response to the request made in Chartered Civil Engineer in May 1950, and repeated at intervals in the Journal.

Prestressed Concrete Development.—The Committee is about to review developments which have taken place in the past five years. The Supplement to the Bibliography on Prestressed Concrete for the year 1952 has been published and Supplements for 1953 and 1954 are being prepared.

Quality of Concrete in the Field.—The Report of this Committee will shortly be published.

Sea Action.—Reports on Series XIII timbers, which are being tested at Colombo, Singapore, and Upnor, are being received regularly.

Soil Mechanics and Foundations.—The Supplement to the Bibliography on Soil Mechanics for 1952 has been published and Supplements for 1953 and 1954 are being prepared.

Vibrated Concrete.—The work of this Committee is well advanced; a draft report has been prepared and this is under consideration.

British Standards Institution.—During the year a number of members have been invited to represent the Institution on technical committees of the British Standards Institution.

Codes of Practice.—New arrangements for the preparation of Codes of Practice came into effect on 1st April, 1954.

As a result of discussions between the Council for Codes of Practice for Buildings (Ministry of Works), the professional Institutions concerned and the British Standards Institution, it has been agreed that a Council for Codes of Practice should be established within the British Standards Institution, to be responsible for all work on Codes of Practice. Committees will be set up under the Council and initially these will cover civil engineering; building construction and engineering services; mechanical engineering; electrical engineering.

The Council will have, within the British Standards Institution, the status of a Divisional Council and, in the preparation of new Codes of Practice, will consult all the professional and other interests concerned with the projects in question.

Mr. A. S. Quartermaine, C.B.E., M.C., Past-President, has been elected Chairman of the new Council.

Public Relations.—Three Christmas Lectures for Boys were arranged at the Institution as follows:—

"Marine Salvage Operations," by Commodore T. McKenzie, C.B., C.B.E.

"Diving in the Royal Navy," by Lieutenant-Commander G. M. Lawther, R.N.

"The Harnessing of Water in Power Development," by Mr. T. A. L. Paton, B.Sc.(Eng.), M.I.C.E.

and good attendances were recorded.

Arrangements were also made to supply to the Cheshire Education Committee, in connection with a Careers Exhibition they organized at Calday Grange Grammar School, a selection of photographs depicting typical civil engineering works. These photographs were subsequently exhibited by the same body for a five-day course for Grammar Schools' Careers Masters.

Relations with the Institution of Mechanical Engineers and the Institution of Electrical Engineers.—The closest association has continued to exist between the Institution and the Institution of Mechanical Engineers and the Institution of Electrical Engineers, particularly in educational matters; engineering education policy has played an increasingly important part in the activities of these Institutions. Representations have been made to the Minister of Education and her advisers on the question of higher technological education in the United Kingdom and to the Colonial Secretary in relation to the development of engineering education in the Colonies. The three Institutions are also playing their part in the exchange of information between the continental countries and the United States on methods of engineering education in diverse countries, and a second round-table conference (the first having been held in London in January 1953) is being held at Zurich in September 1954.

Accounts.—The accounts for the year ending on the 31st March, 1954, which have been duly audited, are detailed in Appendix IV of this Report and may be summarized briefly as follows :—

The *Total Income* for the year amounted to . . .	£94,579
(as compared with £89,598 last year) including £432 for Income Tax recovered. Subscriptions, Entrance Fees, and Examination Fees totalled £89,645 (as compared with £85,772 last year), and Dividends and Interest received amounted to £2,374 (as compared with £2,189 last year).	
The *Total Expenditure* charged against the year's Income amounted to	£91,276
(as compared with £88,832 last year).	
The *General Revenue Account* therefore results in a credit balance on the year of	£3,303
The *General Revenue Account Surplus* amounted to £26,896 on the 31st March, 1954, made up as follows :—	
Balance brought forward 1st April, 1953 . .	£23,593
Add Surplus for year to 31st March, 1954 . .	£3,303
	£26,896

Cash at Bankers and in hand amounted to £43,596 (compared with £50,003 last year) at the close of the financial year, owing to the receipt, as in past years, of a substantial proportion of the current subscriptions during the first quarter. This balance is required to finance expenditure during the remainder of the year.

The actual expenditure during the year on "Publications Account" amounted to £37,542 (compared with £39,121 last year), of which £26,131 represented the cost of the Proceedings, etc. This expenditure was relieved by credits for advertisements, sales, etc., of £18,362 (against £16,673 last year), leaving the net expenditure for the year at £19,180 (compared with £22,448).

The Repairs and Renewals Reserve credit balance has been reduced by £5,838 during the year, viz. from £9,583 to £3,745.

On Trust Funds Income Account there was received a total of £2,214 and the expenditure amounted to £1,791.

During the year, sums of £21 in interest and £12 for sales of reports, etc., have been credited to the research into the Deterioration of Structures exposed to Sea Action.

Prizes and Scholarships.—A Charles Hawksley Prize of £150 for the 1953 Competition was awarded to Mr John Powlesland, B.A., A.M.I.C.E., and consolation prizes to Mr P. J. Gadd, B.Sc., A.M.I.C.E. (£75), Mr E. J. Johnson, Stud.I.C.E. (£75), and Mr D. E. Jared, A.M.I.C.E. (£10). William Lindley Scholarships to the value of £120 per annum were awarded to Mr Charles Damar Dawson for three years. A Dennison Scholarship to the value of £40 was awarded to Mr G. R. Cameron, Stud.I.C.E., for one year.

Rockefeller Foundation Bursaries in Public Health Engineering.—During the year, the second of the three-year period for which the Institution has agreed to administer funds to provide bursaries for post-graduate study and research in public health engineering in universities in the United Kingdom, eleven awards were made, nine being for post-graduate courses and two for research work.

Conversazione.—The Conversazione was held at the Institution on the evening of the 18th June, 1953, when 1,336 members and guests and their ladies were present.

Annual Dinner.—The Annual Dinner of the Institution was held on the 29th April, 1954, at the Dorchester Hotel, London.

Nominations and Appointments.—The following appointments have been made or renewed by the Council during the year :—

Sir William Halcrow	British National Committee, World Power Conference.

Mr H. J. B. Harding, B.Sc. Mr H. B. Sutherland, S.M.	British National Committee, International Society of Soil Mechanics and Foundation Engineering.
Mr Ralph Freeman, C.B.E., M.A. Mr L. Scott White, O.B.E.	National Consultative Council, Ministry of Works.
Mr F. S. Snow	Building Apprenticeship and Training Council, Ministry of Works.
Mr J. N. Peirce Mr Ralph Freeman, C.B.E., M.A. (Deputy)	Tribunal of Appeal under the London Building Acts, 1930–1939.
Mr Gilbert Roberts, B.Sc.	Organizing Committee for a Conference on the Welding of Steel Structures.
Mr H. F. Cronin, C.B.E., M.C., B.Sc.	Trustee for an Endowment Fund, Cornish Engines Preservation Society.
Sir Arthur Whitaker, K.C.B., M.Eng. Mr Arthur Floyd, C.B.E., B.Sc.	Joint Committee for Conditions of Contract.
Mr H. F. Cronin, C.B.E., M.C., B.Sc.	Public Health Engineering Advisory Committee, Imperial College of Science and Technology.
Dr Norman Davey	Exploratory Committee on Concrete Technology, City and Guilds of London Institute.
Mr A. B. Porter	Supreme Governing Body, University of Liverpool.
Mr H. C. Husband, B.Eng.	Court of the University of Sheffield.
Sir Herbert Manzoni, C.B.E.	Governing Body of Loughborough College of Technology.
Professor W. Norman Thomas, C.B.E., M.A., D.Phil., M.Sc.	Moderator for the Diploma in Civil Engineering, Institute of Technology, Loughborough.
Brigadier C. C. Parkman, C.B.E.	Engineering Advisory Committee, Liverpool.
Mr L. R. A. Kidd, B.Sc.	Engineering Advisory Committee, University of Nottingham.
Mr E. J. Manson, B.Eng.	Building Advisory Committee, Rotherham Technical College.
Mr C. G. Kent	Building and Engineering Advisory Committees, Royal Technical College, Salford.

Mr T. H. P. Veal, B.Sc.	Advisory Committee for Building and Civil Engineering, Wolverhampton Education Committee.
Mr P. E. Sleight, M.Eng.	Joint Advisory Committee for Building, Southern Regional Council for Further Education.
Mr Harold Savage, M.B.E., B.Sc.	Joint Advisory Committee for Engineering, Southern Regional Council for Further Education.
Mr Arthur Floyd, C.B.E., B.Sc. Mr R. W. Foxlee, C.M.G., C.B.E. Mr. H. Shirley Smith, O.B.E., B.Sc.	Board of the Professional Engineers Appointments Bureau.

Brigadier A. C. Hughes, C.B.E., T.D., D.L., B.Sc., was a member of the British Delegation at a meeting of the Commission of the Permanent International Association of Road Congresses, held in Paris in July 1953.

Sir William Halcrow attended the annual meeting of the International Commission on Large Dams held in Paris in September 1953, when he was re-elected a Vice-President for a further period of three years.

As Chairman of the British National Committee of the Permanent International Association of Navigation Congresses, Sir William Halcrow also attended the Eighteenth Congress held in Rome and led the delegation at the request of Sir Gilmour Jenkins, who was unable to act as leader.

Mr Ralph Freeman, C.B.E., M.A., represented the Institution at the Centenary Commemoration of the Association des Ingénieurs de la Faculté Polytechnique de Mons on the 17th and 18th October, 1953.

International Engineering Congresses.—The XVIIIth Congress of the Permanent International Association of Navigation Congresses was held at Rome in September 1953. Six Papers were sponsored by the British National Committee and presented at the Congress.

Several meetings have been held of the Special Committee set up by the British National Committee to study the depths of water to be provided in seaports, referred to in last year's Annual Report. The Special Committee set up Panels to consider different aspects of the problem but no Report has yet been published.

At the invitation of the Council, the Executive Committee of the International Society of Soil Mechanics and Foundation Engineering has transferred its Secretariat from Cambridge, Mass., U.S.A., to the Institution. The Council has undertaken to service the Executive Committee and has placed the services of Mr A. Banister at the disposal of the Committee. Mr Banister has been appointed Secretary, by Professor Karl Terzaghi, of the International Society in succession to Professor Donald W. Taylor.

The Third International Conference of the Society was held in Zurich and Lausanne in August 1953, at which Great Britain was fully represented.

The Fourth International Conference is, at the invitation of the British Section, being held in this country in 1957, and the Council has offered to place the building at the disposal of the Society for this Conference.

The British National Society has held four Informal Meetings at the Institution at which articles published in *Géotechnique* have been discussed. These meetings have proved most successful.

Membership of the British Section of the International Commission on Irrigation and Drainage has grown slightly during the year, and the British National Committee arranged for full participation of this country at the Second International Congress held in April 1954 in Algiers.

Kelvin Medal.—On the recommendation of the Award Committee of the Kelvin Medal, the Medal for 1953 has been awarded to Dr C. J. Mackenzie, C.M.G., M.C., M.E.I.C., F.R.S.C., F.R.S.

The Roll.—The Roll of the Institution on the 31st March, 1954, stood at 19,974, the changes which had taken place in it during the year ending on that date being shown in the following table.

	1 April, 1952, to 31 March, 1953							1 April, 1953, to 31 March, 1954						
	Honorary Members	Members	Associate Members	Associates	Graduates	Students	Totals	Honorary Members	Members	Associate Members	Associates	Graduates	Students	Totals
Numbers at commencement	17	2379	9881	34	..	5843	18154	16	2390	10188	34	1517	5025	19170
Transfers—Associate Members to Members	..	+82	−82	..	..	..		..	+106	−106	..	..	..	
Elections	1	6	545	1	..	..		..	5	707	..	..	..	
Admissions	..	..	..	..	1536	890	+2994	..	..	..	..	1093	821	+2636
Restored to Roll	..	1	10	..	..	4		..	..	6	..	2	2	
Deceased	1	62	67	1	..	8		..	59	61	..	..	4	
Resigned	..	15	69	..	2	64		..	23	44	..	2	51	
Erased	..	1	29	..	..	54		..	6	29	1	..	73	
Elected as Associate Members	..	..	..	..	13	164		..	..	..	..	103	178	
Admitted as Graduates	..	..	..	..	..	809		..	..	..	..	..	689	−1832
Removed over-age	..	..	..	..	..	610	−1978	..	..	..	..	..	496	
Failed to complete:—Transfer	..	..	..	..	..	..		..	..	..	..	..	..	
Election	..	..	1	..	..	..		..	..	1	..	..	..	
Admission	..	..	..	..	4	3		..	..	..	..	5	7	
							+1016							+ 804
Numbers at termination	*16	2390	10188	34	1517	5025	19170	16	2413	10660	33	2502	4350	19974

* H.M. Queen Elizabeth who, prior to her accession, was an Honorary Member, has consented to become Patron of the Institution.

The full list of deaths and resignations is given in Appendix III, and the Council record with especial regret the deaths of Joseph Newell Reeson (former Member of Council), and of Edmund Graham Clark (Secretary of the Institution).

Acquisitions.—The Council have received, on behalf of the Institution, a portrait of Mr H. F. Cronin (President 1952–1953) painted by Edward I. Halliday.

An oil painting of Sir Bradford Leslie, former M.I.C.E., painted by his brother George Dunlop Leslie, R.A., was presented by Miss M. L. Spence, a grand-daughter of Sir Bradford Leslie.

The Secretaryship.—The Council desire to place on record their high appreciation of the services rendered to the Institution by the late Mr Edmund Graham Clark, C.B.E., M.C., M.Sc., M.I.C.E., who had been Secretary of the Institution since 1937 until his untimely death on the 23rd April, 1954. Mr Graham Clark had been on the Staff of the Institution for nearly 40 years and was due to relinquish his post on reaching the retirement age of sixty-five later this year.

The Council acknowledge especially the part played by Mr Graham Clark in strengthening the close relationship which now exists between the Institution and the Institution of Mechanical Engineers and the Institution of Electrical Engineers. The co-operation also between National Engineering Societies in the Commonwealth, Western Europe, and the United States of America owes a great deal to the personal efforts of Mr Graham Clark as Secretary.

The Council have appointed Mr Alexander McDonald, B.Sc., M.I.C.E., to succeed the late Mr Graham Clark.

APPENDIX I

ORDINARY MEETINGS

Presidential Address of Mr W. P. Shepherd-Barron, M.C., T.D.

"The Construction of Two Concrete-Lined Tunnels for the Machkund Hydro-Electric Project, South India," by G. A. Gauld, B.Sc., M.I.C.E., and R. J. Newport, B.Sc., A.M.I.C.E.

"The Pimlico District Heating Undertaking," by Bryan Donkin, B.A., M.I.E.E., A. E. Margolis, Dipl. Ing., and C. G. Carrothers, B.Eng., M.I.Mech.E., M.I.C.E.

"The Engineer Task in Future Wars," by Major-General G. N. Tuck, C.B., O.B.E.

"The History and Construction of the Foundations of the Asia Insurance Building, Singapore," by W. J. R. Nowson, B.Sc.(Eng.), A.M.I.C.E.

"Woodhead New Tunnel: Construction of a Three-Mile Double-Line Railway Tunnel," by P. A. Scott, B.Sc., M.I.C.E., and J. I. Campbell, M.I.C.E.

The James Forrest Lecture on "The Geological Survey of Great Britain," by W. J. Pugh, O.B.E., D.Sc., F.R.S.

"Owen Falls, Uganda, Hydro-Electric Development," by Sir Charles Westlake, M.I.E.E., R. W. Mountain, B.Sc.(Eng.), M.I.C.E., M.I.E.E., and T. A. L. Paton, B.Sc.(Eng.), M.I.C.E. (Joint Meeting with the Institution of Electrical Engineers.)

"Owen Falls: Constructional Problems," by D. P. Bertlin, M.Eng., M.I.C.E., and Henry Olivier, C.M.G., M.Sc., Ph.D., M.I.C.E.

AIRPORT ENGINEERING DIVISION MEETINGS

"The Effects of Jet Aircraft on Airfield Pavements, and Associated Problems," by D. H. Carrack, A.M.I.C.E., and D. G. Robertson, M.Eng., A.M.I.C.E.
Lecture on "The Control of Aircraft Movements at Airports," by Clifford Heyes, B.Sc.(Eng.), A.M.I.C.E., and E. J. Dickie, M.B.E.
"Construction of a New Runway at Amman, Jordan," by A. R. Macrae, B.Sc., A.M.I.C.E., and A. F. Smith, A.M.I.C.E.

HYDRAULICS ENGINEERING DIVISION MEETINGS

"Measurement and Utilization of the Water Resources of the Nile Basin," by H. E. Hurst, C.M.G., M.A., D.Sc.
"Rainfall, Run-off, and Storage: Elan and Claerwen Gathering Grounds," by C. A. Risbridger, B.Sc.(Eng.), M.I.C.E., and W. H. Godfrey.
"Land Drainage in England and Wales," by E. A. G. Johnson, C.B.E., B.Sc.(Eng.), M.I.C.E.

MARITIME AND WATERWAYS ENGINEERING DIVISION MEETINGS

"Overhaul and Repair of Lock Gates in the Port of London," by J. T. Williams, B.Sc.(Eng.), A.M.I.C.E.
"Site Exploration for Maritime and River Works," by M. J. Tomlinson, A.M.I.C.E.
"Extensions at Takoradi Harbour," by A. J. Clark, B.Sc.(Eng.), M.I.C.E., and J. H. A. Broughton, B.Sc.(Eng.), A.M.I.C.E.

PUBLIC HEALTH ENGINEERING DIVISION MEETINGS

Lecture on "Atmospheric Pollution: Causes, Effects, and Prevention," by Albert Parker, C.B.E., D.Sc.
Lecture on "Public Health Engineering in Developed and Underdeveloped Countries," by Dr R. P. Burden.
"River Severn Scheme for the Water-Supply of Coventry," by R. le G. Hetherington, O.B.E., M.A., M.I.C.E., and J. C. A. Roseveare, *Jun.*, D.S.O., B.Sc.(Eng.), M.I.C.E.

RAILWAY ENGINEERING DIVISION MEETINGS

"Bridge Investigation, Ceylon Government Railways, 1949–51," by Conrad Gribble, O.B.E., M.I.C.E.
"Railway Civil Engineering in the United States of America," by I. M. Campbell, B.Sc.(Eng.), A.M.I.C.E., and N. J. Nicholls, B.Sc.(Eng.), A.M.I.C.E.
"Wear of Steel Rails: a Review of the Factors Involved," by John Dearden, M.Sc., A.M.I.C.E.

ROAD ENGINEERING DIVISION MEETINGS

"The Design and Construction of a High-Speed Test Track for Motor Vehicles," by Ralph Freeman, C.B.E., M.A., M.I.C.E., and J. A. Neill, B.Sc.(Eng.), A.M.I.C.E.
"British Highway Bridge Loading," by William Henderson, B.Sc., A.M.I.C.E.
"The Road Surface as a Factor in Street Lighting," by A. W. Christie, M.A., B.Sc.

STRUCTURAL AND BUILDING ENGINEERING DIVISION MEETINGS

"A Moment Distribution Method for the Analysis and Design of Structures by the Plastic Theory," by M. R. Horne, M.A., Ph.D., A.M.I.C.E.
"Design and Construction of a Prestressed Concrete Framed Transit Shed for the Port of London Authority," by N. N. B. Ordman, B.Sc., A.M.I.C.E., and I. S. S. Greeves, A.M.I.C.E.
"Design and Construction of the Superstructure of the Marshal Carmona Bridge at Vila Franca de Xira, Portugal," by T. J. Upstone, M.Sc., A.M.I.C.E., and W. N. Cardno.

WORKS CONSTRUCTION DIVISION MEETINGS

Lecture on "Swedish Underground Hydro-Electric Power Stations," by J. F. Hagrup.
"Design and Construction of Rama VI, Surat, and Bandara Bridges in Thailand," by O. A. Kerensky, B.Sc.(Eng.), M.I.C.E., and K. E. Hyatt, B.Sc.(Eng.), M.I.C.E.
"Civil Engineering Construction under Water," by J. R. Malcolm, B.Sc.(Eng.), M.I.C.E., and J. A. Lewis, M.B.E., B.A., A.M.I.C.E.

APPENDIX II*

GLASGOW AND WEST OF SCOTLAND ASSOCIATION

Mr Stanley D. Canvin (M.), Chief Engineer and General Manager of Glasgow Corporation Water Department, succeeded Mr Liston Carnie (M.) as Chairman of the Association.

In his Inaugural Address the Chairman traced fully the organization of his department and then discussed the general training of water engineers and provided a permanent record of the proper functioning of a large water-supply undertaking.

The feature of this Session's Ordinary Meetings has been the extension of the Association's activities to Inverness, where the first yearly programme of four meetings has been held with great success. This expansion allows a large number of members of the Institution—not necessarily all members of this Association—to join in the activities of the Institution, and has produced lively and interesting discussions.

The usual number of meetings have been held in Glasgow, two features being a Paper by Mr Hugh Sutherland (A.M.) on "The Education and Training of Civil Engineers" and a "Discussion on the Legal Aspects of Civil Engineering Contracts, Specifications, etc.," when Mr Kenneth Thomas, B.A., LL.B., Legal Adviser to the Federation of Civil Engineering Contractors, arbitrated.

Mr Sutherland's Paper produced a record discussion in which so many members joined that the meeting had to be closed before all could speak, and written contributions were received. The proceedings were recorded verbatim and, after editing, Mr Sutherland's Paper and the discussion were circulated to all members present.

The Discussion on Legal Aspects was unique in its conception and operation and aroused wide interest among local engineers. The discussion of legal issues covered almost the whole field of civil engineering and was conducted in an invigorating forceful manner, Mr Thomas providing many new and interesting legal opinions.

The Annual Dinner of the Association, held in November 1953, allowed the members the pleasure of meeting the President and gave the Association the opportunity to wish Mr Graham Clark a happy, long, and well-earned retirement. Mr Graham Clark kindly replied to the Chairman's remarks.

The Summer Meeting of the Association was held at Forest Hills Hotel in the Trossachs, near Aberfoyle, and allowed the members of the Association and ladies to make a thorough inspection of the water-supply undertaking of the City of Glasgow, by kind permission of the Corporation. Buses were run from Glasgow for members not able to stay at the Hotel.

The Graduates' and Students' section has had a very lively winter, and enthusiasm over the presentation of Graduates' and Students' Papers has been excellent as a result of the efforts made by Mr H. B. Sutherland (A.M.), the Chairman. The usual bright and enjoyable combined dance with the Graduate and Student members of the Institutions of Mechanical and Electrical Engineers was held during the Session.

NORTH-WESTERN ASSOCIATION

The Chairman for the 1953–54 Session has been Brigadier C. C. Parkman, O.B.E. (M.), a consulting engineer in practice at Liverpool. In his address delivered on the 1st October, 1953, he dealt with specialization and the need for co-ordination of all branches of the civil engineering profession under one Charter and one Institution in a similar manner to other great professions. He then considered the problems arising from the natural water-cycle; the provision and purification of water for use;

* In this Appendix the following abbreviations are used:—Member (M.): Associate Member (A.M.): Graduate (G.): Student (S.).

decontamination and disposal of used water; disposal of water surplus to requirements; conservation of water for navigational purposes; and control of water in land erosion and accretion. In view of the engineering and technical aspects associated with almost every problem of to-day Brigadier Parkman stressed the need for the inclusion of a greater number of engineers amongst policy makers at the highest level.

At the commencement of the Session Mr J. T. Firth (M.) relinquished the Honorary Secretaryship of the Association, a position which he had so efficiently filled for five years. Fortunately, the Association did not lose the benefit of his experience and administrative ability, for he was elected a Vice-Chairman.

The number of meetings held during the Session was 15, including the inaugural meeting, the Annual General Meeting, and joint meetings. The latter were with the Lancashire Engineering Society at Preston, the Institution of Structural Engineers and the Reinforced-Concrete Association in Manchester, and the Liverpool Engineering Society in Liverpool. One of the Ordinary Meetings was held in Liverpool and one in Chester.

The subjects covered a very wide field including the design of motorways; the control of water for food production; building in prestressed concrete; load-factor design in reinforced concrete; site exploration; piling and foundations with special reference to the glacial deposits in the north-west area. A Graduates' and Students' meeting was again devoted to talks by Graduates and Students on their experiences in the first years of professional employment. Many Students, Graduates, and university undergraduates took part in the discussion which followed. The Dugald Clerk Lecture was repeated in Manchester on the 18th February, 1954, by Mr R. R. W. Grigson (M.), whose subject was "Plant for the Construction and Maintenance of Highways."

Visits were made to the Haweswater Aqueduct which is now approaching completion, to an opencast coal site at Bolton, and finally to the Hawarden Bridge Steelworks of Messrs John Summers and Sons, Ltd, the latter visit being followed two days later by the meeting at Chester previously referred to when the new iron-making and steel-making plant at Shotton was fully described by Mr J. F. R. Jones.

The Annual Dinner was held at the Midland Hotel, Manchester, on the 11th March, 1954, when the President and Secretary of the Institution were present. Among the guests were Lord Woolton, Chancellor of the Duchy of Lancaster, The Lord Mayor, and the Dean of Manchester and representatives of the University, College of Technology, and other engineering societies.

Professor R. J. Cornish (M.) continued to represent the Association on the Council of the Institution.

MIDLANDS ASSOCIATION

Mr T. H. P. Veal (A.M.), Lecturer at the University of Birmingham, took over the Chairmanship of the Association from Mr C. A. Risbridger (M.). In his Chairman's Address, delivered in Birmingham on the 8th October, 1953, he reviewed the whole aspect of civil engineering and its progress in recent years; he covered the fields of roads, railways, water-supply, sewerage and sewage disposal, drainage and town planning. The Address was repeated by Mr Veal at the Meeting of the Association in Loughborough later in the month.

Twelve Ordinary Meetings were held during the 1953–54 Session, seven in Birmingham, four in Loughborough, and one in Nottingham. In addition Joint Meetings were held in Birmingham with the Institutions of Mechanical and Electrical Engineers, and in Wolverhampton with the Institution of Municipal Engineers. The subjects dealt with were varied and included structures, water-supply, bridges, railways, highways, land drainage, and education.

There were three Graduates' and Students' Meetings and in addition a Joint Meeting with the Graduates and Students of the Institutions of Mechanical and Electrical Engineers.

During the summer months, visits were made to the Castle Donington power station which is under construction, and to the Gunthorpe pipe bridge over the River Trent at Nottingham. The Students also arranged visits to the Croft granite works and to the B.S.A. works.

For the third summer in succession an Annual Meeting was held which included dinner at Stratford-upon-Avon and a visit to the Shakespeare Memorial Theatre. A

visit was first made to Charlecote Park where tea was taken. About 100 were present including the President and Mrs Cronin.

The Annual Dinner of the Association was held at Birmingham on the 26th November, 1953, and was attended by the President and Secretary of the Institution, the principal guests being the Lord Mayor of Birmingham and Professor Thomas Bodkin.

Mr C. A. Risbridger (M.) continued to represent the Association on the Council of the Institution and Sir Herbert Manzoni (M.) was again elected as an ordinary member of Council.

NORTHERN COUNTIES ASSOCIATION

During the summer of 1953 several visits were arranged. In June there was an attendance of 142 to inspect the new large dry dock under construction at Messrs Smith's Dock Ltd, North Shields. In September, members inspected works at the Middle Beck sewer, Middlesbrough, and in October a second visit was made to the sites of the New Stella generating station at Blaydon-on-Tyne. The Graduates' and Students' Section inspected some river works of the River Wear Commissioners.

Mr J. A. Rodwell (M.) was elected Chairman for the Session 1953–54 and delivered his Chairman's Address at Newcastle, Middlesbrough, and Carlisle. He gave an account of the development of the Durham County Water Board with whom he had been associated, as Chief Engineer, for so many years.

Eight meetings were arranged at Newcastle. The subjects discussed at these meetings were :—power station buildings ; hydrographic surveying ; plant for highway construction ; testing of road aggregates ; the new deep-water quay and the iron-ore-discharging plant at Tyne Dock, South Shields ; a rock-filled dam at Freetown ; and public health engineering services at Costa Rica.

Six meetings were arranged at Middlesbrough. The subjects discussed at these meetings were :—atmospheric pollution in U.S.A. ; river control ; the Lackenby works ; plant for highway construction and maintenance, and the design of Wilton main drainage scheme. Two meetings were held at Carlisle.

The Graduates and Students elected Mr R. S. Cogden (A.M.) as Chairman of their Section and seven meetings were arranged at Newcastle. The subjects discussed were :—astronomy schemes for widening the river Wear ; glacial problems as they affect civil engineers ; the digital computer applied to the solution of structural problems, and the design and construction of rapid gravity filters.

There was a good attendance of members and their ladies at a Dinner and Dance held in January 1954 at Durham Castle.

The Annual Dinner was held in the Royal Station Hotel, Newcastle, on the 8th April, 1954. This year is the centenary of the birth of the late Sir Charles Parsons, O.M., K.C.B., M.I.C.E., F.R.S., the distinguished Tyneside engineer who was a member and Chairman of the Association and Sir Claude Gibb, C.B.E., D.Sc., M.S., F.R.S., also an eminent engineer and Managing Director of Messrs C. A. Parsons, attended the Dinner and spoke in tribute to Sir Charles and his work. The President of the Institution, Mr W. P. Shepherd-Barron, civic representatives, and other distinguished persons also attended.

YORKSHIRE ASSOCIATION

Mr D. Currie (M.), City Engineer and Surveyor, Leeds, succeeded Professor R. H. Evans (M.) as Chairman of the Association. In his address, given at Leeds on the 25th September, 1953, and at Hull on the 21st October, 1953, Mr Currie dealt with the civil engineer in local government and described the work of the municipal engineer.

In addition to the Chairman's Address, the Annual Dinner and Branch Meetings, the Association has met on seven occasions. Three meetings were held in Sheffield, two in Leeds, and one each in York and Scunthorpe. The meeting at Scunthorpe was held jointly with the Yorkshire Branch of the Institution of Structural Engineers. Subjects discussed at these meetings were :—traffic engineering in the U.S.A. ; atmospheric pollution ; principles of railway signalling ; shaft-sinking accidents ; reconstruction of a soaking-pit building ; bridgeworks in Sheffield ; and land drainage. A visit to the colour-light signalling installation of the British Railways at York was very well attended and proved extremely interesting.

In addition to the above meetings, three meetings have been arranged by the

Graduates' and Students' Section. At the first of these, Papers on the Brotherton railway tunnel, the Coquet viaduct, and prestressed concrete in locomotive-shed roofs were presented. A Paper on methods of testing concrete was given at the second meeting. A further meeting was arranged in conjunction with the Junior Section of the Institution of Municipal Engineers.

A very successful Dance was held on the 19th December, 1953, arranged jointly with the Graduates' and Students' Sections of the Institutions of Electrical and Mechanical Engineers.

Mr T. H. Jones (M.), Engineer and Manager of the Water Department, Hull, a founder member of the Hull and East Riding Branch, has served this Session as the first Branch Chairman.

A varied programme was arranged for the Branch and meetings have been well attended. In addition to the Association Chairman's Address the Branch heard Papers on :—site exploration; engineer tasks in future wars; jetties and fenders; economic factors in the choice of design. One meeting was devoted to films and a further meeting to papers by Graduates and Students.

The President, Mr W. P. Shepherd-Barron, attended the Annual Dinner which was held at the Queens Hotel, Leeds, on the 25th March, 1954. Among the guests were the Lord Mayor and Lady Mayoress of Leeds, Lord Milner of Leeds, Mr P. Stanley Price, and representatives of kindred associations.

Mr H. Foster (M.), Deputy City Engineer and Surveyor, Sheffield, has represented the Association on the Council for the Session.

SOUTH-WESTERN ASSOCIATION

Mr B. E. Ireland (M.), who served this Association so ably as Hon. Secretary from 1946–51, succeeded Mr N. S. Cox (M.) as Chairman. His address, given in Bristol on the 15th October, 1953, and repeated in Plymouth on the 22nd October, covered some aspects of the advances made during the past thirty years in civil engineering contracting, with particular reference to the improved equipment now available. The address was illustrated by a number of photographs.

There were nineteen meetings during the Session, four of these held in conjunction with Local Associations of other Institutions. Three meetings took place at Plymouth, and two at Exeter. Papers presented covered many subjects, including suspension bridge development; reinforced-concrete gasholder tank; rubber in roads; district heating; foundations; prestressed-concrete shed; tunnel work; land drainage, etc.

A Miller Prize was awarded to Mr M. F. Maggs (now A.M.), of the City Engineer's Department, Bristol, for his Paper on "Road Traffic Engineering, with reference to some recent Bristol Surveys," and a certificate was presented to him during the opening meeting of the Session on the 15th October, 1953.

A Paper entitled "Modern Methods of Permanent Way Maintenance and Renewal," by G. E. W. Peart (G.), was given on one Graduates' and Students' Evening, and on the other evening a discussion on "The Training of Graduate and Student Civil Engineers" took place. The attendance on the latter occasion was not as good as was expected, but the discussion was very successful. Copies were printed and distributed.

By kind permission of British Railways, a visit was made on Tuesday, 22nd September, 1953, to the Swindon Railway Workshops. The party arrived on site immediately after lunch at Swindon, when the engineers personally showed members over the works. Another all-day visit was made on Wednesday, 8th July, to Exeter, where the City Engineer, Mr J. Brierley (A.M.), arranged for members to visit the new buildings in the centre of the city before lunch, and afterwards showed them over the pumping station at Pynes.

A combined Dance with the Institutions of Mechanical, Structural, and Aeronautical Engineers was held at the Royal Hotel, Bristol, on the 4th December, 1953.

The Annual Dinner of the Association was held on the 18th March, 1954, at the Royal Hotel, Bristol. The President attended and guests present included the Sheriff of Bristol and Lady, the Master of the Society of Merchant Venturers, the Vice-Chancellor of the University of Bristol, Chairmen of Local Associations of other Institutions, and Mr T. H. P. Veal (A.M.), and Mr F. W. Taylor (A.M.), Chairman of the Midland and Southern Associations respectively, together with their Ladies. The Dinner was followed by a Dance.

Mr G. E. Scott (M.) was again elected as the Association's representative on Council.

NORTHERN IRELAND ASSOCIATION

Mr J. J. Hartley (A.M.) succeeded Dr Denis Rebbeck (M.) as Chairman for the Session and delivered his address on the 19th October, 1953, which dealt with the geological aspects of site investigation and was illustrated with lantern slides.

Seven meetings were held, one of them being a joint meeting with the Northern Ireland Association of the Institution of Structural Engineers. As is the usual custom, one meeting was organized by the Graduates and Students. Excluding the Chairman's address, one Paper was by an Associate Member of the Association, one by a Student of the Association, and another by a Belfast chemist. The remaining lectures were given by visitors to Belfast. During the Session five visits were arranged.

The Association co-operated with the Ministry of Health and Local Government in organizing two courses on ordinary and prestressed concrete. One course was designed for junior engineers and site supervisors and a second for qualified engineers. The courses were of two and three days' duration and given by the Research and Development Division of the Cement and Concrete Association. For the engineers' course demonstrations of prestressing were given.

The President of the Institution was present at the Annual Dinner of the Association held in the Midland Hotel, Belfast, on the 11th February, when about 105 members and guests attended. The principal guest was the Minister of Finance. Since this was the 21st Session of the Northern Ireland Association the opportunity was taken to present Mr Robert Ferguson (M.), who has held the position of Hon. Treasurer since the inception of the Association, with some silverware as an appreciation of his work. Mr J. E. Harben (M.), the first Hon. Secretary of the Association, was also present at the dinner.

A successful social occasion in the form of a dance was held on the 9th April, 1954.

Attendances at meetings of the Association have continued to be satisfactory. The present strength of the Association is 31 Members; 175 Associate Members; 66 Graduates; 97 Students.

SOUTHERN ASSOCIATION

The Session opened on the 15th October, 1953, when Mr F. W. Taylor (A.M.), Borough Engineer of Aldershot, who succeeded Mr J. P. M. Pannell (M.) as Chairman, delivered his address at Chichester. Mr Taylor's address referred to special surveying problems with which he had been confronted during his career as a municipal engineer and to the installation of heat pumps as a means of heating large buildings.

During the Session, meetings were held at Southampton, Brighton, Portsmouth, Chichester, and Bournemouth. There were ten meetings in all, including two joint meetings with the South-Eastern District of the Institution of Municipal Engineers and one joint meeting with the Southern District of the Institution of Municipal Engineers. The general standard of attendance at these meetings has been good, the average being approximately 100 per meeting.

The Annual Summer Meeting last year was held in May. Mr and Mrs H. F. Cronin, together with the Secretary of the Institution, joined 120 members and guests for a cruise in Southampton Water on board M.V. "Balmoral." The Annual Luncheon was served in the vessel.

Mr P. E. Sleight (M.) has been nominated to the Council for 1954–55. He has represented the Association for the past two Sessions.

SOUTH WALES AND MONMOUTHSHIRE ASSOCIATION

Mr E. C. Roberts (M.), the City Engineer of Cardiff, was elected Chairman of the Association and took office on the 5th October, 1953. The Chairman's address entitled "Some Random Reflections on the Role of the Civil Engineer in a Planned Economy" was published in the January 1954 issue of the Chartered Civil Engineer.

Six ordinary meetings have been held in Cardiff and one in Swansea. The average attendance for the Session was 42. The meeting which attracted the largest attendance (108) was held at Cardiff when a Paper on "The Lynmouth Disaster" was given by Mr C. H. Dobbie (M.). One joint meeting was held in Cardiff with the Institution of Structural Engineers.

One visit was made to Llangyfelach By-Pass Scheme.

During the Session, two ordinary meetings and two visits were held by the Students' and Graduates' Section. The Third Annual Ball proved to be as successful as the previous two.

The Annual Dinner held at the Royal Hotel on the 17th March, 1954, was again a great success. The President, Mr W. P. Shepherd-Barron, honoured the Association with his presence.

Lt-Col. R. H. Edwards (M.) served in his fifth year as Council Member.

The Committee met before each ordinary meeting and the average attendance has been 12. The Honorary Secretary, Mr T. Leslie Lowe (M.), has attended three meetings in London of the Honorary Secretaries of Local Associations.

Mr J. F. A. Baker (A.M.), one of the Vice-Chairmen, will not be able to take any further part in the activities of the Association as he has been appointed Deputy Chief Engineer of the Ministry of Transport in London.

Mr E. C. Roberts (M.) and Mr E. J. Powell (M.) represented the Association on the Ministry of Works Building and Civil Engineering Regional Joint Committee, the Welsh Joint Education Committee, and the Cardiff Technical College Engineering and Allied Trades Sub-Committee respectively.

EDINBURGH AND EAST OF SCOTLAND ASSOCIATION

The Chairman for the Session has been Mr Colin F. Armstrong (M.), Superintending Civil Engineer, H.M. Dockyard, Rosyth, who succeeded Mr Charles H. Smith (M.), Chief Engineer (Scotland) for Messrs George Wimpey & Co. Ltd. Mr Armstrong, in his inaugural address on the 14th October, 1953, discussed "The Maintenance of Works and Buildings," with special application to that very complex group which comprises a large naval establishment. He described the various forms used in the preparation of the programme for the year and outlined the procedure followed in carrying it out in order to give an even flow of work and to ensure that defects were not overlooked. He touched also on the accounts aspects of maintenance and concluded with the following advice to young engineers engaged on maintenance work :—(1) Never tolerate bad workmanship and never forget to give a word of praise when it is deserved ; (2) plan the work for the year and carry it out evenly throughout the year ; (3) record the periodical work done so that the information will be of use in the future ; (4) record all petty repairs in such a way that you know that they have been done and in reasonable time.

The number of meetings held in Session 1953–54 was eleven, not including the Annual Dinner and the Dance (a new feature for Edinburgh), but including the inaugural meeting, the Annual General Meeting, two special Graduates' and Students' meetings and two outside meetings at Aberdeen and Dundee respectively. The subjects dealt with "Shipbuilding and the Civil Engineer," by Mr W. G. N. Geddes (at Edinburgh and Dundee) ; "The Conon Basin Hydro-Electric Scheme, Fannich and Luichart Tunnels," by Messrs J. B. B. Newton and J. Murray (Edinburgh and Aberdeen) ; "Repair of Breakwater at Alderney," by Mr R. W. Bishop ; "Portobello Power Station Reconstruction," by Mr. C. M. Wilson ; and one Students' Paper by Mr. R. W. Drummond and two Graduates' Papers by Messrs J. D. Addly and B. N. Harvey, registered for the Miller Prize Competition. Films were shown after the Annual General Meeting. At the first Graduates' and Students' meeting there was an interesting discussion between Civil Engineers and Contractors on "Design and Construction," and at the second meeting the subject was "Piling Methods," fully illustrated by films, slides, and photographs collected from many sources.

The average attendance at the ordinary meetings was about 80, the small decrease as compared with 1952–53 being due mainly to the smaller attendance of Graduate and Student Members.

Five Papers read on the 14th January, 1953, were registered for the 1952–53 Miller Prize Competition and four prizes were awarded to the authors : Messrs Mackenzie (G.), Birse (G.), Watson (S.), and Collier (S.).

As a result of negotiations between the immediate past Chairman and the Principal, Heriot-Watt College, Edinburgh, and with the support of the Council, Members of the Association have now the use of the College Library with the right to borrow books from the Civil Engineering Section, and it has been agreed that part of the Association's annual grant of £20 should be spent by the Heriot-Watt College on books of a civil engineering nature.

The Annual Dinner was held in November 1953 when Scottish members of the Association were particularly pleased to welcome a fellow countryman, Mr W. P. Shepherd-Barron, as President. There was an attendance of 125 members and guests.

Recent visits to engineering works included Portobello Power Station, Lothians Structural Development Co., Macmerry, Costain's prestressed concrete unit factory, and the Errochty-Pitlochry Hydro-Electric Scheme, the last named being the most largely attended.

The usual two Christmas Lectures were arranged by the "Lectures to Schools" Joint Committee and were attended by over 200 secondary schoolboys; this year the Lectures were provided by the Institution of Electrical Engineers, the subjects being "Television" and "Modern Magnetism."

Mr W. P. Haldane (M.) completed four years' office as the Association's representative on the Council and his place was taken by J. L. White (M.), public works contractor, now the only Member of Council resident in the East of Scotland area.

APPENDIX III

Deaths and Resignations

The full list of deaths is as follows (E. refers to election, T. to transfer, and A. to admission :—

Members (59).—Herbert Leon Abrahams, B.Sc. (E. 1922, T. 1938); Charles Buxton Anderson, *C.M.G.*, *I.S.O.* (E. 1925); Alec Richard Chesters Ball, B.Sc. (E. 1935, T. 1946); Gilbert Alfred Ballard, *O.B.E.* (E. 1912, T. 1934); Laurence Bendelow (E. 1927, T. 1950); Alfred Brown Ernest Blackburn, *C.B.E.* (E. 1901, T. 1920); Thomas George Bocking (E. 1934); Philip Piggott Brown (E. 1907, T. 1937); Harry Frederick Carew-Gibson (E. 1896, T. 1913); Joseph MacLeod Carey, *O.B.E.* (E. 1935); Thomas Carter (E. 1918); John Ernest Croasdaile, M.A., B.A.I. (E. 1899, T. 1903); *Sir* Bernard D'Olier Darley, *C.I.E.* (E. 1906, T. 1931); Christian Leslie Dyce Duckworth, B.Sc. (E. 1917, T. 1937); Charles Edmund Fonseka (E. 1932, T. 1947); Frank Richard Freeman, B.Sc.(Eng.) (E. 1916, T. 1928); Sukhendra Nath Ghose, B.Sc. (E. 1920, T. 1926); Martin Gimson (E. 1910, T. 1928); George Tertius Glover (E. 1896, T. 1913); Arthur Thomas Gooseman (E. 1921); William Hugh Gorton, *T.D.* (E. 1921); William Arthur Gray, *M.C.*, M.Sc. (E. 1916, T. 1936); Frank Harold Greenhough, B.A. (E. 1928, T. 1939); William Arthur Harrison, *O.B.E.*, M.Eng. (E. 1927, T. 1937); John Black Morrison Hay, *M.C.*, M.Sc. (E. 1924, T. 1936); Thomas Edward Hett Heywood (E. 1903, T. 1923); William Hood, *O.B.E.* (E. 1927, T. 1946); John Houston (E. 1928); David Arnold Howell, *C.I.E.*, *O.B.E.* (E. 1915, T. 1932); Daniel Peter Howells (E. 1907, T. 1921); *Col.* George Eric Howorth, *O.B.E.*, M.C., B.Sc. (E. 1915, T. 1926); George Mathews Hutton (E. 1919, T. 1950); James Sinclair Jackson, *M.C.*, B.A., B.Sc. (E. 1917, T. 1930); Sigvald Johannesson, D.Eng. (E. 1929); Wallace Strickland Lake (E. 1905, T. 1920); Alexander Burns Lawson, B.Sc.(Eng.) (E. 1917, T. 1929); James Lowe (E. 1902, T. 1921); William Gibb McCracken, B.Sc. (E. 1920, T. 1933); James McGregor, *D.S.O.* (E. 1906, T. 1919); Arthur John Whyte McIntosh, B.Sc. (E. 1929, T. 1944); John Richard Matthew (E. 1917, T. 1945); Thomas Humphrey Matthews, M.A. (E. 1935); Henry Bridges Molesworth (E. 1889); William Muirhead (E. 1896, T. 1904); Joseph Leslie Musgrave (E. 1943); Reginald William Newman (E. 1893, T. 1912); William Onyon, *M.V.O.*, (*Engr-Capt.*, R.N., Rtd) (E. 1926); Geoffrey Parker (E. 1906, T. 1928); James Davis Pearson, B.A., B.E. (E. 1903, T. 1913); Neil James Peters (E. 1900, T. 1921); *Professor* Harold Percy Philpot, B.Sc.(Eng.) (E. 1913, T. 1940); Joseph Newell Reeson (E. 1894, T. 1914) (*former Member of Council*); John Hall Rider (E. 1896, T. 1902); Peter Rudolf Swart, B.Sc. (E. 1940, T. 1952); William Henry Thomas (E. 1919, T. 1944); Salman Budrudin Tyabji (E. 1912, T. 1943); *Lt.-Col.* Harry Williamson (E. 1917, T. 1930); James Williamson, *C.B.E.* (E. 1907, T. 1923); *Sir* Johnstone Wright (E. 1934).

Associate Members (61).—Henry Wilfrid Barnes, B.Eng. (E. 1921); Harry Latour Bazalgette (E. 1911); Stephen Augustus Bennett (E. 1915); Robert Bonner (E. 1911); Ignatius Bulfin, B.A. (E. 1896); James Thomas Harold Richard Hugh Ledicotte Burrell (E. 1904); Lionel Calisch (E. 1908); Humfrey Alleyne Carte (E. 1894);

Ganapati Iyer Chellam, B.E. (*E.* 1938); Albert Croad (*E.* 1912); *Professor* Purushottam Ganesh Dani, B.Sc.(Eng.) (*E.* 1910); Arthur Ernest Darby (*E.* 1908); John Elder Duncan, B.Sc.(Eng.) (*E.* 1924); John Ellis (*E.* 1910); Herber Howell Evans (*E.* 1932); George McLean Gibson, *O.B.E.* (*E.* 1913); Albert John Golding, *O.B.E.*, B.Sc. (*E.* 1919); *Lt.-Col.* John Vickers Hall, *O.B.E.*, *T.D.* (*E.* 1927); Wilfred Hall, M.A. (*E.* 1900); Frederick Thomas Harrison (*E.* 1912); George Reinhard Harrison (*E.* 1923); Hubert Haughton (*E.* 1926); Ralph Hilton (*E.* 1946); *Emeritus Professor* Alexander Robert Horne, *O.B.E.*, B.Sc.(Eng.) (*E.* 1913); Frederic Horspool (*E.* 1910); John Owen Jones (*E.* 1924); Edward Robert Kendrick (*E.* 1914); James Lee, B.Sc. (*E.* 1935); Roger Ferdinand Vogel Leech (*E.* 1913); Charles Delacour Le Maistre, *C.B.E.* (*E.* 1907); Sidney Land Luker, B.Sc. (*E.* 1918); Joseph Patrick Lumley, B.E, (*E.* 1921); Alexander Allen McClelland (*E.* 1918); John McGrory (*E.* 1909); Daniel Macleod (*E.* 1918); Louis Samuel Rolf Mangenie, B.Sc. (*E.* 1931); Robert Christopher Melville, B.Sc. (*E.* 1939); Richard Edward Michael (*E.* 1907); John Edwin Walden Moore (*E.* 1950); James Thomson Morrison (*E.* 1913); Richard Cecil Moss, B.A., B.A.I. (*E.* 1905); Vincent Packer, M.C.E. (*E.* 1933); Robert Wilford Peake, B.Sc. (Eng.) (*E.* 1923); George Frederick Poppleton (*E.* 1938); Leslie Pyke (*E.* 1893); John Robertson (*E.* 1919); *Sir* John Owen Sanders, *C.M.G.* (*E.* 1921); William Harley Saxton, B.Eng. (*E.* 1918); Ralph Sephton, B.A. (*E.* 1908); James Ainsworth Settle (*E.* 1896); Richard Degge Sitwell (*E.* 1911); Vernon Charles Smith (*E.* 1910); Charles Vivian Stephens (*E.* 1917); Stanley Sweeney (*E.* 1926); Alfred Edward Nelson Taylor, B.Sc.(Eng.) (*E.* 1931); Leonard Godfrey Pinney Thring, M.A. (*E.* 1898); Herbert George Tisdall, B.Sc.(Eng.) (*E.* 1909); Robert Edgar Walsh, *M.C.*, M.A., B.Sc.(Eng.) (*E.* 1921); Henry Thomas White (*E.* 1894); Henry Norman Wilford (*E.* 1927); Herbert Charles Palairet Woolmer (*E.* 1897).

Students (4).—William Paterson Hunter, B.Sc. (*A.* 1946); Peter Robert Johnston Kirkpatrick (*A.* 1945); Douglas Gordon McKinstry (*A.* 1946); Maurice Sidney Spinks (*A.* 1949).

The following resignations have been received :—

Members (23).—*Sir* Robert Charles Bristow, *C.I.E.* (*E.* 1915, *T.* 1920); Hugh Thomas Carleton (*E.* 1925); Alfred Arthur Davis (*E.* 1908, *T.* 1931); Spenser Dennis, B.E. (*E.* 1929, *T.* 1939); Percy Dougall (*E.* 1914, *T.* 1948); Arthur Reginald Ellison (*E.* 1905, *T.* 1922); Thomas Edwin Nelson Fargher, Ph.D., M.Eng. (*E.* 1918, *T.* 1936); Edmund Austin Gardiner, *O.B.E.*, B.Sc.(Eng.) (*E.* 1925, *T.* 1949); Wilfred Eric Randall Gurney (*E.* 1919, *T.* 1936); Ernest George Horton, B.Sc.(Eng.) (*E.* 1916, *T.* 1941); Alfred William Kohring (*E.* 1904, *T.* 1920); James Cecil Martin, *O.B.E.* (*E.* 1934); John Francis Hunter Nicolson, *O.B.E.*, *M.C.* (*E.* 1928, *T.* 1947); Crosland Smith Richards, B.A. (*E.* 1919, *T.* 1936); Kenneth William Shortt (*E.* 1942); Charles Milton Spofford (*E.* 1924); Viraraghava Srinivasan, B.E. (*E.* 1934, *T.* 1949); Edward Gentry Timbrell, B.Sc.(Eng.) (*E.* 1921, *T.* 1934); Geoffry Frederick Walton (*E.* 1912, *T.* 1928); Alexander Webster, *C.I.E.* (*E.* 1923, *T.* 1936); Leo Francis Weldon (*E.* 1928, *T.* 1950); Arthur Norman Wilson, M.Sc. (*E.* 1935, *T.* 1946); William Yates (*E.* 1912, *T.* 1926).

Associate Members (44).—Bernard Adkins, M.A. (*E.* 1948); Harold Allen (*E.* 1920); Eric Reynolds Bartrum (*E.* 1918); William Stephen Benton (*E.* 1923); Frank Louis Boydell (*E.* 1915); William Ephrie Bullen, B.Sc. (*E.* 1929); William Bernard Burrow (*E.* 1918); James Cullimore, M.A. (*E.* 1912); Leonard Trueman Dallow (*E.* 1919); Frederick Mead Daniel (*E.* 1920); Ralph Thomas Edge, B.A. (*E.* 1914); Ernest Frederick Edwards (*E.* 1919); George Collin Ellinger (*E.* 1918); Albert Leonard Evans (*E.* 1914); Westley Yorke Feurtado (*E.* 1938); Dermot William Grehan, M.A., B.A.I. (*E.* 1939); Wallis Bertrand Hardy, B.Sc.(Eng.) (*E.* 1929); Bertie Steward Hayward (*E.* 1921); John Gordon Henderson, B.Sc. (*E.* 1904); Geoffrey Howard Hunt, B.Sc. (*E.* 1933); Ernest Courthope Last (*E.* 1913); George Lees (*E.* 1914); Anthony St George Lyster, *C.S.I.*, B.A. (*E.* 1914); Arnold Maude (*E.* 1912); Geoffrey Hindmarsh May (*E.* 1911); Douglas Mends Mends-Gibson, *M.C.* (*E.* 1922); Anthony Charles Dorian Meyjes (*E.* 1920); Edward Warwick Newton, B.E. (*E.* 1946); Alexander Herbert Pirie (*E.* 1910); Major Gerard Evelyn Poole (*E.* 1913); George Powis (*E.* 1914); Charles Quartanos (*E.* 1912); Charles Vincent Richards, B.Sc.(Eng.) (*E.* 1913); Frederic Charles Riley (*E.* 1935); Alec Joseph Skinner, *M.C.*, B.Sc.(Eng.) (*E.* 1918); Edward Lambart Sladen (*E.* 1915); Archibald Spence (*E.* 1925); Thomas Storer, *M.B.E.* (*E.* 1945); James Ardern Taylor (*E.* 1919); Geoffry Barry Poole Thompson,

M.C. (*E.* 1913); George Walker (*E.* 1907); Charles Edward Whitcombe (*E.* 1928); Harry Charles White (*E.* 1917); Walter Llewelyn Williams, *M.B.E.* (*E.* 1924).

Graduates (2).—Kajetan Maria Jozef Dzierzykraj-Morawski (*A.* 1953); Barry Hardcastle, B.Sc. (*A.* 1952).

Students (51).—Derek Allen (*A.* 1952); Athol Kendrick Attwood (*A.* 1951); Michael William Farmer Banfield (*A.* 1951); George Edgar Furness Barrow (*A.* 1949); Armin Berger (A. 1944); Kieran Stanislaus Brennan (A. 1946); Stuart Berry Bridge (*A.* 1947); Joseph Forsyth Scott Carruthers, B.Sc. (*A.* 1945); Alan Ferguson Chalmers (*A.* 1953); Brian Leonard Clarkson (*A.* 1950); Wilfred Shipham Cragg (*A.* 1947); Keith Robert Crossman (*A.* 1949); Dennis Gordon Davis, B.A. (*A.* 1948); Frederick Michael Dawe (*A.* 1945); John Day (*A.* 1951); John Percy de A'Echevarria, B.Eng. (A. 1950); Gordon Ray Duff (*A.* 1953); Lindsay Philip Frank (*A.* 1950); John Edward Franklin (*A.* 1947); Roger Cedric Glasbey (*A.* 1952); Jaipal Singh Gupta (*A.* 1950); Frank Gordon Holroyd (*A.* 1949); James William Nicholson Hoseason (*A.* 1945); David Loxley Hughes (*A.* 1950); Derek Wally Hunt (*A.* 1947); Ian Hunter (*A.* 1947); Alan Anderson Hyland (*A.* 1945); Michael Robert King (*A.* 1947); Peter Langford-Jones (A. 1951); Colin Frank Lawton (*A.* 1945); Howard Clarke Macnamara (*A.* 1951); Thomas McGregor McNie (*A.* 1951); Raymond Wilfred Victor Marsh (*A.* 1948); William Nicol Monteith (*A.* 1948); John Edward Nethaway, B.Sc.(Eng.) (*A.* 1951); Brian Preston Opie, B.E., B.Sc. (*A.* 1951); Robert Ormerod, B.Sc.Tech. (*A.* 1949); Bertram Roland Osborne (*A.* 1946); David Christopher Peters (*A.* 1951); Derrick Ian Francis Prall (*A.* 1944); Michael Joseph Anthony Redding (*A.* 1948); Donald Alexander James Reid-Smith (*A.* 1949); Francis Reilly (*A.* 1953); Geoffrey John Roberts, B.Sc.(Eng.) (*A.* 1949); Donald Sutherland Ross (*A.* 1952); Reginald Edwin Smith (*A.* 1947); Julian Frederick Spear (*A.* 1950); Colin Keith Turnbull (*A.* 1949); Vernon Andrea Ventura (*A.* 1946); Donald Westlake (*A.* 1946); Michael Kingsley Williams (*A.* 1952).

THE INSTITUTION

BALANCE SHEET

31 March 1953 £		£ s. d.		£ s. d.
	INSTITUTION CAPITAL ACCOUNT			
414,759	*As per last Account*			414,758 16 10
	INSTITUTION BUILDING SINKING FUND			
	As per last Account		1,925 14 8	
	Add : Allocation for year to date		450 0 0	
	Interest on Investments and Income Tax refunded		70 14 5	
1,926				2,446 9 1
	REPAIRS AND RENEWALS RESERVE			
9,582	*As detailed on page 486*			3,745 17 0
	GENERAL REVENUE ACCOUNT SURPLUS			
	Balance at 31st March, 1953		23,593 12 0	
	Add : Surplus for the year to date, *page 487* . .		3,302 17 0	
23,594				26,896 9 0
449,861				447,847 11 11
	CREDITORS—			
	Sundry Creditors		17,113 8 6	
	War Memorial Fund		490 9 11	
19,984				17,603 18 5
	REVENUE IN SUSPENSE			
	Proportion of subscriptions, examination fees, etc. received relating to the period after 31 March, 1954			
47,490				49,255 2 11
517,335				514,706 13 3
	TRUST FUNDS			
	Capital Accounts		69,529 16 9	
	Unexpended Income—			
	Balance per last account . . .	8,018 14 6		
	Add : Income received for the year to date	2,214 5 2		
		10,232 19 8		
	Less : Expenditure on Scholarships, Prizes, Lectures, etc. .	1,791 18 0		
			8,441 1 8	
77,532				77,970 18 5
	SEA ACTION COMMITTEE ACCOUNT—			
	Balance at 31st March, 1953		957 5 11	
	Add : Interest and other receipts for the year to date		33 5 1	
957				990 11 0
595,824				£593,668 2 8

REPORT OF THE AUDITORS TO THE MEMBE

We have obtained all the information and explanations which to the best of our knowledge kept by the Institution so far as appears from our examination of those books. We have examin of account. In our opinion and to the best of our information and according to the explanati 31st March, 1954, and the general revenue account gives a true and fair view of the surplus for

London, 14th May, 1954

IL ENGINEERS

31st MARCH, 1954

31 March 1953 £			£ s. d.	£ s. d.
	FREEHOLD PROPERTY—Institution Building—			
375,768	*At cost, as per last Account*		..	375,767 16 10
	INSTITUTION INVESTMENTS at or			
85,878	under cost		..	85,878 7 5
	Market value, £78,939—(1953, £74,607)			
	INSTITUTION BUILDING SINKING FUND			
1,872	Investments at cost		2,375 14 8	
	Market Value, £2,365—(1953, £1,715)			
54	Cash awaiting investment		70 14 5	
				2,446 9 1
3,760	**DEBTORS**			7,017 1 4
50,003	**BALANCES AT BANKERS AND CASH IN HAND**			43,596 18 7
517,335				514,706 13 3
	TRUST FUND ASSETS—			
	Capital :—			
	Investments	69,494 10 6		
	Market value, £58,546			
	Balance at Bankers	35 6 3		
			69,529 16 9	
	Unexpended Income—			
	Investments	437 0 11		
	Market value, £360			
	Balance at Bankers	8,004 0 9		
			8,441 1 8	
77,532				77,970 18 5
	SEA ACTION COMMITTEE ACCOUNT—			
	£700 3% Savings Bonds 1955/65 at cost . . .		700 0 0	
	Market value, £679			
	Balance at Bankers		290 11 0	
957				990 11 0
595,8?4				£593,668 2 8

G. V. BURNS, for *Secretary*

THE INSTITUTION OF CIVIL ENGINEERS.

ef were necessary for the purposes of our audit. In our opinions proper books of account have been above Balance Sheet and annexed general revenue account which are in agreement with the books n us the said Balance Sheet gives a true and fair view of the state of the Institution's affairs at the ended on that date.

A. RAE SMITH } Auditors
J. A. JOHNSTON }

RESERVE FOR REPAIRS AND RENEWALS TO STRUCTURE, FURNITURE, FITTINGS AND MACHINERY

1952–53 £		£	s.	d.	£	s.	d.
15,256	BALANCE, per last account				9,582	15	5
	Add CREDITS during the year—						
560	Allocation of Interest on Investments				250	0	0
	Institution Revenue Account—						
2,500	Amount provided for the year, *page 487* . . .				5,500	0	0
18,316					15,332	15	[illegible]
8,734	Less NET EXPENDITURE during the year				11,586	18	[illegible]
9,582	BALANCE carried forward, per Balance Sheet, *page 484*				3,745	17	7

PUBLICATIONS EXPENDITURE

		£	s.	d.	£	s.	d.
	To EXPENDITURE during the year—						
26,811	Proceedings, etc.	26,131	9	6			
2,349	"Chartered Civil Engineer" . .	1,936	1	8			
524	"Géotechnique"—Expenditure less Receipts	71	1	11			
1,166	Charters, By-laws and Lists of Members	448	12	6			
758	Engineering Abstracts	795	11	11			
6,941	Salaries and Pension Premiums . .	7,729	4	9			
148	*Miscellaneous Publications* . . .	—	—	—			
424	Reporting and Sundries	430	1	9			
39,121		37,542	4	0			
16,673	Less Credits for Advertisements, Sales, Subscriptions, etc.	18,362	6	10			
22,448	As per General Revenue Account, *page 487*				19,179	17	7

RESEARCH

		£	s.	d.	£	s.	d.
	To EXPENDITURE during the year—						
978	Salaries and Pension Premiums	1,416	0	8			
13	Travelling to Committees	28	5	1			
393	Printing of Sundry Reports	306	4	1			
4	Sundry Expenses	2	13	1			
1,388					1,753	2	[illegible]
453	Less Sales of Proceedings and Reports				1,693	18	[illegible]
935	As per General Revenue Account, *page 487*				59	4	[illegible]

GENERAL REVENUE ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1954

INCOME.

1952–53 £		£	s.	d.	£	s.	d.
68,376	Subscriptions received applicable to the financial year 1953–54		..		70,619	8	10
7,836	Entrance Fees		..		9,305	13	0
125	Life Composition		..		250	0	0
	Interest, Dividends, etc.—						
	On Institution Investments	2,125	18	7			
	On Deposit Account less Interest paid	248	6	7			
	Income Tax recovered for the year 1952–53	432	4	8			
2,626					2,806	9	10
9,560	Examination Fees for the April and October 1953 Examinations		..		9,720	7	9
193	Higher National Certificates—receipts less expenses		..		212	19	0
882	Library Fund Donations				1,664	4	0
89,598	Total Income		..		94,579	2	5

Deduct EXPENDITURE.

1952–53 £		£	s.	d.	£	s.	d.	£	s.	d.
14,446	House and Establishment Charges				16,396	1	5			
	Repairs and Renewals Reserve—									
2,500	Amount provided for the year, *page 486*				5,500	0	0			
21,409	Salaries and Wages (including staff pensions premiums)				21,228	15	7			
4,795	Stationery, Postage, etc.				4,053	13	5			
22,448	Publications—*see page 486*				19,179	17	2			
935	Research—*see page 486*				59	4	10			
4,249	Library				4,582	11	9			
582	Library Reorganization				437	14	5			
7,659	Examination Expenses				7,527	6	10			
	Grants and Contributions—									
—	Local Associations and Overseas Groups	5,815	8	3						
—	Overseas Advisory Committees	88	18	9						
—	Other Bodies	99	13	10						
4,406					6,004	0	10			
208	Annual Dinner				140	12	2			
894	Conversazione				1,052	13	6			
325	Legal and other Professional Charges				412	17	0			
250	Public Relations Committee Expenses				210	1	6			
2,035	Engineering Conferences				1,603	4	6			
1,031	Travelling Expenses to Committees				1,351	11	10			
210	Other Expenses				662	2	5			
450	Institution Building—Sinking Fund Allocation				450	0	0			
—	Coronation Expenses				423	16	3			
88,832	Total Expenditure							91,276	5	5
Surplus 766	Balance, being Surplus for the Year carried to Balance Sheet							£3,302	17	0

CORRESPONDENCE

on a Paper published in Proceedings, Part I, May, 1954

Paper No. 5983

"The Pimlico District Heating Undertaking" †

by

Bryan Donkin, B.A., M.I.E.E.
Abraham Elia Margolis, Dipl. Ing., and
Charles George Carrothers, B.Eng., M.I.Mech.E., M.I.E.E.

Correspondence

Mr John Fox observed that for several years past, there had been much vague discussion about the Pimlico scheme but, until the presentation of the Paper, very few facts regarding the actual working of the scheme had been released.

It was satisfactory to have unbiased confirmation of the conclusions (1) and (5) on p. 284, but the economics of the scheme were still rather left in the dark.

It was known that coal production was practically static, that the coal utilization efficiency of gas, measured at the point of continuous use, was better than that for electricity, and moreover that gasworks produce coke. Whatever criticisms might be levelled at the reactive properties of the latter, it was, after all, a useful smokeless fuel suitable for most domestic appliances, an important point at a time when the supply of solid fuel to householders was severely restricted. Yet, it was indicated by the Federation of British Industries [11] that national coal consumption was likely to exceed national production by about 50 million tons in another ten years' time, and, of that total, 27½ million tons would be required by the British Electricity Authority to meet the demands necessitated by its programme of power-station construction. Those figures were not necessarily accurate, but if present trends continued, they could not be far from the mark.

A cooling tower resembled a whited sepulchre, although it must be conceded that it was impossible to dispense with every one. However,

† Proc. Instn Civ. Engrs, Part I, vol. 3, p. 259 (May, 1954).
[11] "A National Fuel Policy." Fed. Brit. Industries (Feb. 1952).

it was not always realized that the Electricity Act of 1947, definitely charged the B.E.A. with responsibility for investigating methods for the utilization of heat obtained in connexion with the generation of electricity from their stations. Far more was now known about Pimlico, but that scheme had been initiated before the B.E.A. came into existence. There was also the case of an East London brewery supplying exhaust heat to adjacent blocks of flats, but what else had been done in Britain ? The productivity report on fuel conservation[12] pointed out that in some areas of the United States of America, and particularly in the south, the electricity companies went to great lengths to divert space heating away from electricity, actively campaigning against its use for that purpose. Mention was also made in the same report of thermo-electric district heating schemes in the United States and so it would seem that further comment on American practice was superfluous. Why could not the B.E.A. distribute steam or hot water in suitable areas in addition to three-phase current ? The Authority provided power and light, but why not also heat in another form ?

Much could be gained by trying out full-scale experiments in areas such as the devastated sites of central Bristol and the City of London, as well as in some rural areas, say near new towns, where perhaps intensive horticulture under glass was a major industry.

The time was now appropriate to make further comments on those proposals. A firm of very high standing had prepared a report on a " Heat Distributing Service " for the City of Bristol, which had been discussed with the Planning Technical Sub-committee of the Corporation of Bristol towards the end of 1942. No more had been heard of that scheme, which, of course, could not be developed during the war years or immediately afterwards. Yet, Mr G. M. Rawcliffe, Professor of Electrical Engineering in the University of Bristol, had seen fit to publish an excellent article in *The Manchester Guardian* on the 18th November, 1953, pointing out that electricity was too valuable for reckless use, as well as developing the subject of the " scientific ethics " of fuel policy.

Turning now to the City of London, in recent months the situation had been transformed completely with regard to the granting of building licences. The time was ideal to go ahead with plans for a thermo-electric heating scheme, the exhaust heat to be used entirely in commercial premises. If it was objected that site values were very high, back-pressure or pass-out generating plant could be erected below street-level.

The United States had been mentioned, but there had also been notable developments in district heating in Germany during recent years, particularly at Hamburg, where it was very popular and where the cost of the connexions, and of all apparatus required in the buildings, was now being met by the consumers. Furthermore, in 1952, three back-pressure

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12 " Fuel Conservation," Productivity Report, Brit. Prod. Council (Sept. 1953).

turbo-alternators, each of 50 megawatts, had been ordered for Charlottenburg, and the first of those should be on load within about 2 years.

A study of press advertisements in general, as well as of other propaganda, would reveal immediately that the Electrical Development Association was spending large sums of money on the promotion of electricity sales to domestic consumers, a state of affairs which was plainly contrary to the national interest. In fact, as recently as the 23rd November, 1953, the Minister of Fuel and Power had agreed with Mr Gerald Nabarro, M.P., in the House of Commons, that a pamphlet recently published by the E.D.A. and entitled "Facts about Fuels" was open to criticism. Mr Geoffrey Lloyd had gone on to say that it made certain misleading comparisons between fuels and that he had informed the British Electrical Authority of his opinion.

Mr Joseph Rawlinson remarked that considerable attention had been directed in recent months to the necessity for conserving the coal resources of the country and to the reduction of atmospheric pollution. District heating on a large scale made a handsome contribution to both those objectives.

In spite of the urgent need to install district-heating schemes little progress would be made, unless substantial reductions could be made in the initial capital cost of construction. The weekly charges to be passed on to the consumer to pay for capital and interest were so high that it made many of the schemes unworkable.

For the benefit of those who were not too familiar with the geography of the Pimlico area, and the circumstances surrounding the project, it was only fair to point out that the site was very conveniently placed for receiving heat from the Battersea Power Station. The fact that there was a tunnel under the river in about the right place, capable of taking the heating mains from one side of the river to the other, presumably at very low cost, was entirely fortuitous. The eight- and ten-storey flats were of considerable length and possessed basements, which enabled some of the supply pipes to be constructed under exceptionally favourable conditions.

Those facts must have been of very great importance when the financial side of the undertaking had been under consideration and in consequence the cost of laying the main must have been fairly low. The heat load required at each block of flats was probably large enough to make unnecessary the costly procedure of installing numerous underground service connexions in cases where the buildings to be heated were more openly developed than at Pimlico.

Presumably the rates per week as given on p. 269 were the all-in costs. Even so, it would be very unwise to assume that because hot water and space heating had been provided economically to the tenants at the Pimlico Housing Estate and to Dolphin Square, that it would be possible to provide the same quantity of heat at the same rates to any other housing estate of comparable size.

Many local authorities had been and were anxious to install district-heating schemes; many excellent proposals had been prepared and considered but unfortunately most of them had been abandoned for financial reasons.

It was always difficult to determine what was a reasonable charge for hot water and space heating and there were still serious differences of opinion as to the standards of heating required. At Pimlico all the rooms in the flats were heated during the winter months, the living rooms to 65° F. and the bedrooms to 50–55° F. when the outside temperature was 30° F. To supply heat to all the rooms in a flat was expensive and considered by many to be unnecessary. At the outset it laid down a standard which imposed unconditionally an unduly high financial burden on both the owner and the tenants, and if a reduction in standard could be achieved without impairing the general amenities of central heating then so much the better. It was very doubtful whether any local authority would attempt in any future scheme to provide space heating in all rooms of either flats or houses. It was much more likely that the number of heated rooms would be limited to two or possibly three, the living room and landing, and possibly one bedroom in the largest flats. That would give a degree of comfort very much in excess of what was in fact provided in the great majority of homes (of all types) in Britain at the present time.

Was there any other way of reducing the capital costs of those schemes? The present practice in Britain of laying supply mains and even, in some cases, service mains in expensive tunnels or ducts would have to be seriously revised or at any rate curtailed. Some Dutch engineers have reduced their installation costs by laying specially prepared pipes directly in the ground. It was claimed that that method had worked very successfully for some years and the cost of laying the pipes was very much less than for the more usual traditional method mentioned above.

The Authors had referred to the possible saving of fuel when comparing the Pimlico scheme as a whole with the more usual type of apparatus and fittings for supplying hot water and space heating. The calculations had apparently been based on the assumption that each householder burnt about 4 tons of solid fuel per year. From enquiries from many sources and from a careful study of the Ridley report there was much evidence to show that the yearly consumption was probably not more than 3 tons per annum. If that figure was more or less accurate, then the savings shown by the Authors should be reduced from 10,000 tons to 7,000 tons per annum.

It would be very interesting to know whether the Authors would support the practice of the Dutch engineers of placing heating mains and pipes excluding, of course, junctions and expansion joints, directly in the ground without the costly addition of an expensive duct or tunnel.

Some system of metering would have to be found which would enable a tenant to pay for the heat he actually used. Meters of Dutch manufacture were in use on the Continent at the present time; they were

apparently efficient and reliable. Where those were installed the tenant could regulate his consumption of heat in accordance with his own financial resources and in that way the more economically minded tenant could, by a little care, save money. On the other hand a system such as that put a check on the careless or extravagant tenant.

Mr P. M. Ross asked the Authors why in the scheme, as in many other district-heating schemes, the heat was supplied on a flat-rate basis and was not metered to individual consumers. Heat was a commodity akin to electricity in that it was often pleasant to use it extravagantly; for instance, by leaving radiators on and having the windows open to obtain warmth and fresh air at the same time. In that respect, heat could not be compared with water, which was normally supplied on a flat-rate basis, because little satisfaction could be obtained from allowing it to run to waste. By not metering the heat to consumers, even when it could be produced cheaply, the demand on the installation might, through extravagant use, be much greater, and the overall cost to the consumer considerably higher, than it would be if there was a more immediate incentive to economy. A heat meter suitable for installation in each home might be relatively expensive compared with, say, the usual domestic electricity meter, but if the use of such meters could reduce consumption by even a small percentage it would surely be economic to fit them.

The annual heat demand for space heating and hot water supplied in the scheme described was estimated at an average of 535 therms per flat. Would the Authors state whether the consumption of heat in practice had worked out close to that estimate? The total consumption of heat was given in Table 2 but it was not stated how many flats were served by the district-heating undertaking during the period covered by the Table.

On p. 280 of the Paper the total saving in coal achieved by the undertaking was estimated to exceed 10,000 tons per annum for the same quality of heat supplied. The actual saving would probably be much less owing to the increase in the standards of heating which the scheme was able to bring about; no saving at all might result if heat was wasted by the consumers.

For a district-heating scheme using water rather than steam as the distributing fluid, a gas turbine was particularly suitable for supplying both the power and the heat. The efficiency of power generation of a steam turbine was considerably reduced below that of a normal condensing set, by raising the exhaust temperature to a value which was suitable for the district heating circuit. A gas turbine, however, normally gave up its waste heat through a considerable range of temperature; that heat might be transferred to the hot-water system without any reduction in the efficiency of power generation. A 1,000-kilowatt coal-fired closed-cycle gas turbine was now being manufactured and installed in the works of John Brown & Co. (Clydebank) Ltd, and would both generate electricity and supply space heating for several of the machine shops. The ratio of electricity generated to the heat output was about unity, and the efficiency of power

generation was superior to that of a condensing steam turbine of similar size, and very much higher than that of a back-pressure steam turbine.

In general, the ratio between the electricity generated in a power station and the practicable heat load of the surrounding district would almost always be greater than could be supplied by back-pressure steam turbines, even when using the very high steam conditions referred to in the Paper. Gas turbines generating the electricity at high efficiency could therefore supply all the heat required without any increase in fuel consumption in the power station. The coal saved by the distribution of that heat would represent a true saving of the nation's coal resources, and the cost of the heat delivered by the power station to the district-heating scheme would represent only the annual charges on the comparatively small cost of the necessary heat-transfer equipment.

Sir Herbert Williams thought that some of the conclusions on p. 284 did not seem to be justified—particularly the first. On p. 289 the Authors had stated the charges for heating according to the number of rooms in the flat. They had not said whether it represented a profit or a loss by the Westminster City Council and had produced no evidence as to the cost of heating by other methods.

Sir Herbert had been studying the problem of district heating for a considerable time. According to an American document he had read there were, in the United States, a number of successful enterprises. The Wythenshawe (Manchester) scheme, on the other hand seemed to be a financial failure ; so also did the Urmston District Council scheme. In the two latter cases, of course, the heat supply was from a central boiler to individual houses and Sir Herbert thought that those schemes had been wrecked by the heavy transmission losses. Pimlico, however, had every conceivable advantage—proximity to a power station, the tunnel under the river, and distribution to blocks of flats.

The Authors, in reply, said that the absence of details of the finance of the Pimlico District Heating Scheme was explained under the heading " Overall Economy " on p. 275. It had not been found possible to allocate costs between condensing and back-pressure generation at Battersea, nor to the cost of the distribution scheme, because only one section of it had been completed. Mr Fox had referred to the use of coke for domestic space and water heating. Whilst that would avoid the emission of visible smoke it might be noted that where coke was used extensively the presence of small grits in the atmosphere could be very troublesome.

The need for fuel conservation was now a generally accepted fact and the British Electricity Authority were making an intensive investigation of the problem ; a sub-committee had been appointed to report on district heating with particular reference to the Pimlico District Heating Undertaking.

District heating had been considered in detail for new towns and the reconstruction of devastated sites, and as long ago as 1936 (see reference 1,

p. 285) the use of discarded heat for all purposes including horticulture was considered in great detail. As the fuel situation worsened the country would, no doubt, be forced to make greater use of district heating. It was hoped that any development of district heating in London would be on a large scale, but that would not be consistent with Mr Fox's suggestion of the installation of back-pressure or pass-out generating plant below street level. The emission of the products of combustion from such stations would defeat a large part of the object of district heating.

In connexion with the developments in Germany it was interesting to note that one of the Authors, Mr Margolis, had been for many years Chief Engineer of the extensive district-heating scheme in Hamburg and was responsible for the design of it in the first place. Such developments were referred to in the numerous Papers written by him. Some of these are mentioned on p. 285. It might be noted that the Charlottenburg scheme referred to did, in fact, comprise pass-out sets so that the whole of the 50 megawatts output could not be credited to district heating. The development was none-the-less very much to be welcomed and showed that a substantial start was being made to develop district heating in Germany, in the realization of the economic benefits to be provided.

The Authors agreed with Mr Fox's reference to the promotion of electricity sales to domestic consumers for heating purposes of any kind. Propaganda of the kind mentioned could cause considerable harm and it was to be hoped that future publications of that character would not be issued without proper regard to the facts concerned.

Turning to Mr Rawlinson's remarks, it had to be agreed that district heating without combined generation of electricity offered little economic advantage, but there was no doubt that in a suitable site such as Pimlico a cheap supply of heat could be provided by combined generation. The fortuitous advantage of the existing tunnel between Battersea and Pimlico should not, however, be overstressed. Many such sites were in existence without the disadvantage of a river between the power station and the heat consumers. It would also be realized that in the case of new towns it would be possible to provide blocks of flats with basements similar to those at Pimlico for the housing of supply pipes. The tendency in new buildings was necessarily to reduce the area occupied per unit of population and to increase the thermal insulation of the building structure, and for those reasons it could be expected that the economy attained at Pimlico might be realized elsewhere, even with the reduced heat supply suggested. The Authors were not, however, in favour of abandoning the idea of general heating for houses because they were convinced by past experience that, by confining the heat to one or two rooms, a considerable part of the advantage of central heating was sacrificed.

The proposals of the Dutch engineers for heat insulation referred to by Mr Rawlinson were under investigation and showed promise of reducing the cost of distribution schemes.

Little difficulty should arise in deciding what was a reasonable charge for space heating and hot-water supply, for it had to be competitive with alternative means of providing the same service. The real difficulty was to determine the standards of heating required, since they were often made to vary within wide limits according to the capital available and other restrictive influences imposed by a particular scheme.

What was not generally fully appreciated in connexion with the Pimlico scheme was the greatly improved standard of service given at little extra cost compared to that provided by the more conventional methods of heating in general use today. That was a feature which was usually overlooked when reference was made to the amount of the flat-rate charges payable by the tenant.

The Authors agreed with Mr Ross that some consumers used heat extravagantly at times and it was of the utmost importance to discourage any such practices. A heat meter in each home would be the ideal method of doing that but it would put up the cost of heat out of all proportion to any savings effected and it was hoped that experience at Pimlico would confirm that economical operation was possible without the use of individual meters. It was on that and similar points that the Pimlico scheme could be regarded as a prototype.

The actual consumption of heat at Pimlico exceeded the 535 therms per annum quoted. That matter was now under investigation and it was already possible to see from further observations of operating conditions that the excess probably arose from several causes, most of which could be eliminated or avoided as the Undertaking was further developed.

The extent of the coal saving at Pimlico had been dealt with in the replies to other contributors.

With regard to the use of gas turbines for district heating, the most promising development in that direction would appear to be the gas-turbine cycle using steam as the working substance, as described in Mr Field's contribution to the discussion (p. 288). As Mr Ross had pointed out, a development on those lines would lead to a true saving of the nation's coal resources.

The Authors thanked Sir Herbert Williams for his contribution and pointed out that most of the special questions raised by him had been answered above.

Dealing generally with his third point, the Authors considered it doubtful if any direct supply of heat for district heating, without combined generation of electricity, could be operated in competition with modern methods of supplying heat by other means. The point which the Authors had wished to demonstrate was that combined generation of heat and electricity was essential for coal saving and for the economical supply of heat, and that it was important that the ratio R of electrical to heat energy supplied should be made as high as possible.

OBITUARY

EDMUND GRAHAM CLARK, C.B.E., M.C., M.Sc., Secretary of the Institution, died in a nursing home at Eastbourne on the 23rd April, 1954, after a short illness.

Born on the 15th May, 1889, Mr Clark was educated at Felsted School, and graduated in the Faculty of Engineering of the University of Durham. He was a pupil of Mr J. Mitchell Moncrieff, under whom he later served as an engineering assistant on various works on the River Tyne.

Mr Clark joined the staff of the Institution as a technical and editorial assistant, in July 1914, but, being a territorial officer, was mobilized a month later. He served throughout the war in the 50th (Northumbrian) Division T.F., and saw active service in France and Belgium.

Demobilized, as a Staff Captain, in 1919, he rejoined the staff of the Institution and was soon promoted to the post of Chief Technical Assistant. In 1933, he became Chief Assistant, and early in 1937 Acting Secretary, his appointment as Secretary of the Institution being confirmed in December of that year. Mr Clark held this position at the time of his death, although he was to have retired in August.

Whilst Chief Technical Assistant of the Institution, Mr Clark acted as secretary to a number of technical committees, including the committees on The Tabulation of the Results of Heat Engine Trials, Engineering Quantities, and Floods in relation to Reservoir Practice.

Whilst Secretary of the Institution, Mr Clark played a leading part in furthering the close relationship which now exists between the Institution of Civil Engineers, the Institution of Mechanical Engineers and the Institution of Electrical Engineers, and, subsequently, in the work of promoting active co-operation between the principal national engineering societies, not only of the Commonwealth, but also of Western Europe and the United States, which resulted in the formation of the Conference of Engineering Institutions of the British Commonwealth and the Conference of Representatives from the Engineering Societies of Western Europe and the U.S.A.

Following Mr Clark's admission as a Student of the Institution, he was elected an Associate Member in 1914, and transferred to the class of Members in 1938. He became a C.B.E. in the New Year's Honours of 1948.

He leaves a widow and two daughters.

HENRY BRIDGES MOLESWORTH, who died at his home at Limpsfield Chart on the 8th February, 1954, was born at Woolwich on the 7th July, 1855. He was educated at Windermere College and joined

H.M.S. Britannia, Dartmouth, as a naval cadet in 1869. He served in the Royal Navy as a midshipman until May 1873.

In November 1873 he was appointed as an Assistant Engineer to the Public Works Department in India and served, first, on the Northern Bengal State Railway and later on the Jhelum-Pindi State Railway during the Second Afghan War. Later, he was appointed District Engineer on the Bengal State Railway and, subsequently, District Engineer on the Nizam's State Railway.

Mr Molesworth was elected a Member of the Institution in 1889, and was also a Member of the Institution of Aeronautical Engineers.

On his return to England in 1894, he became Chief Engineer on the erection of the Devil's Dyke cable-way, near Brighton. In 1898 he was appointed as manager of a steel works at Manchester and, in 1900, went to Baltimore, U.S.A., on inspection work for Messrs Rendel and Robertson.

In 1902, Mr Molesworth presented a Paper to the Institution on "American Workshop Methods in Steel Construction." *

Also, in that year, he commenced a partnership as a consulting engineer in Westminster, but dissolved this in 1908, when he went into partnership with Mr Walter Molesworth. At about that time he took over from his father, Sir Guilford Lindsay Molesworth, the revision and expansion of *Molesworth's Pocket Book of Engineering Formulae*, adding an electrical supplement and many other features.

Mr Molesworth devised and patented many inventions, including aircraft bomb sights, submarine-detecting apparatus, submarine mines and exploders, and shells for Davis guns.

He was a first-rate seaman and twice won the Duggan Cup of the Cruising Association for cruises round Great Britain and the Mediterranean.

He leaves a son and a daughter.

NEIL JAMES PETERS, who died at his home in Bournemouth on the 26th February, 1954, was born in Antigua, West Indies, on the 25th June, 1873.

He was educated at Craigmore College, Bristol, and at Hartley College, Southampton.

He began his career with Southampton Corporation under Mr William Matthews, M.I.C.E., F.G.S., and subsequently held the position of Deputy Water Engineer at Cardiff. From 1926 to 1938 he was Chief Water Engineer and Manager, Cardiff City Council.

Mr Peters was elected an Associate Member of the Institution in 1900, and transferred to the class of Member in 1921. He was also a Past-President and Member of Council of the Institution of Water Engineers.

He is survived by one daughter and three sons.

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* Min. Proc. Instn Civ. Engrs, vol. 148, p. 58 (1901–1902, Pt II).

CORRIGENDA

Proceedings, Part I, May 1954

p. 372, equation (1), *for* " $w \,.\, h \,.\, B \,.\, n_1$ " *read* $\dfrac{\text{“}w \,.\, h \,.\, B \,.\, n_1\text{”}}{b}$

p. 372, line 3 from bottom, *for* " $wh_1.B\delta h$ " *read* " $wh.B\delta h$ "

p. 378, line 9, *after* " identical " *insert* " and considerably less than the calculated values "

p. 389, *Figs 18.* The line diagram is printed upside down. The part of the diagram labelled " (*a*) Original model " is actually " (*c*) Model with curved downstream face."

p. 392, line 4, *for* " Model A " *read* " The first model "
line 7, *for* " a model " *read* " a second model "
line 9, *for* " Model A to give . . . *Figs 17* and *18* " *read* " the first model to give the stress system shown in *Fig. 19* (*b*) "
line 26, *for* " almost 30 " *read* " about 50 "

p. 396, line 25, *after* " B.A." *insert* " A.M.I.C.E."

p. 396, reference 3, *after* " 3328 " *insert* " , 1945 "

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ANNUAL GENERAL MEETING

8 June, 1954

WILFRID PHILIP SHEPHERD-BARRON, M.C., T.D.,

President, in the Chair

The President, having moved, and the Meeting having agreed, that the Report of the Council, which, as intimated in the May number of *Chartered Civil Engineer*, had been available to Members upon request to the Secretary, be taken as read, said the Report revealed that it had been quite an active year for the Institution. There had been thirty-five meetings at which Papers had been presented, one being held jointly with the Institution of Electrical Engineers. A new Hydraulics Engineering Division had been formed during the Session. The awards in connexion with oral Papers would be announced at the opening meeting of the next Session and the awards for Papers printed in the Proceedings would not be announced during the evening. It had been intended to announce them, but some of the Authors who had been awarded premiums were not corporate Members and therefore were not eligible to attend the meeting.

During the year there had been three important Conferences. That on the North Sea Floods of January February 1953 had been attended by a number of Belgian and Dutch engineers; another, on Welded Structures, had been organized jointly with the Ministry of Works and the Institution of Structural Engineers. Both had been well attended and the Proceedings, when published, would be valuable additions to the literature on the subjects.

The Conference of the Commonwealth Engineering Institutions, which had just ended, had been organized jointly by the three home Institutions, who had acted as hosts. It had been attended by representatives from Australia, Canada, India, New Zealand, and South Africa, in addition to representatives of the three home Institutions. A great deal of useful work had been done in achieving a greater degree of understanding of all the problems of the various Institutions in all countries. The Conference, which had been very successful, would be reported in the Report of the Council for Session 1954–55.

During the year the President had had the pleasure of attending the annual dinners of the various associations; he had welcomed opportunity to meet all the Chairmen, Secretaries, and members of the associations. They were very lively assemblies who took an enormous interest in the Institution.

It was a matter of regret to the Council that there had been insufficient

entries for the Institution Medal and Premium (Local Associations) but it was hoped to hold the competition in October.

The Research Committee and the various sub-committees had been very active; the President thanked the members of those committees for the work which they did, for they had done extraordinarily well and given a great deal of time to the subjects.

The new arrangements mentioned in the Report concerning the Codes of Practice were developing satisfactorily. Friendly co-operation with the Institutions of Mechanical and Electrical Engineers had continued.

Since the Report of the Council had been published, the roll of the Institution had reached 20,000.

Members had read of the untimely death of Mr E. Graham Clark, on the eve of his retirement. He had served the Institution for 40 years and had been Secretary since 1937. His death was a great loss to the Institution. The Council had placed on record their high appreciation of the great service which Mr Clark had rendered to the Institution.

The Institution's new Secretary had arrived in England and would take up his duties at the end of the month.

There being no questions, the President proposed that the Report be received and approved, and this was passed.

The President announced the following report of the Scrutineers on the ballot for the election of the Council for Session 1954–55:—

THE INSTITUTION OF CIVIL ENGINEERS
COUNCIL 1954–1955

President

DAVID MOWAT WATSON, B.Sc.

Vice-Presidents

William Kelly Wallace, C.B.E.
Harold John Frederick Gourley, M.Eng.
Sir Frederick Arthur Whitaker, K.C.B., M.Eng.
Professor Alfred John Sutton Pippard, M.B.E., D.Sc., F.R.S.

Other Members of Council

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Professor John Fleetwood Baker, O.B.E., M.A., Sc.D., D.Sc.
Stanley George Barrett (*Northern Counties*).
Graham Townsend Bennett, O.B.E., B.Sc.
Arthur Borlase, T.D. (*S. Wales & Monmouthshire*).
Professor Ronald James Cornish, M.Sc. (*North Western*).
Edgar Algernon Cross, B.Sc. (*Canada*).

Walter Edmund Doran, O.B.E., B.A., B.A.I.
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Henry Foster (*Yorkshire*)
Richard William Foxlee, C.M.G., C.B.E. (*Colonies*).
Ralph Freeman, C.B.E., M.A.
Sir George Herbert Fretwell, K.B.E., C.B.
Angus Anderson Fulton, B.Sc.
Arthur Clifford Hartley, C.B.E., B.Sc.
Philip Haviland Haviland, O.B.E., B.Sc. (*N. & S. Rhodesia*).
Nathaniel Harvey Hunt (*India & Pakistan*).
Sir Claude (Cavendish) Inglis, C.I.E., M.A.I., F.R.S.
John Holmes Jellett, O.B.E., M.A.
William Linn (*Glasgow & West of Scotland*)
Percival St Lawrence Lloyd.
Robert McCreary, O.B.E., M.C., B.A., B.Sc. (*Northern Ireland*).
George Matthew McNaughton, C.B., B.Sc.
Sir Herbert (John Baptista) Manzoni, C.B.E.
Donald Stuart Gore Marchbanks, D.S.O., M.B.E. (*New Zealand*).
Graham Morgan, B.Sc. (*Colonies*).
Thomas Angus Lyall Paton, B.Sc.
Adrian Benson Porter.
Joseph Rawlinson, C.B.E., M.Eng.
Charles Arthur Risbridger, B.Sc. (*Midlands*).
Brendan Francis Saurin, B.Sc.
Henry Schrader, M.Sc., B.Sc. (*South Africa*).
George Edward Scott, O.B.E., V.D., M.Eng., B.Sc. (*South Western*).
James Herbert Siddons, M.Eng. (*Ceylon*).
Percy Edward Sleight, M.Eng. (*Southern*).
Hubert Shirley Smith, O.B.E., B.Sc.
Marcus George Russell Smith, M.B.E., B.Sc.
Major-General Sir Clive Selwyn Steele, K.B.E., D.S.O., M.C., V.D., B.C.E. (*Australia*).
Charles Bruce Townend, C.B.E., B.Sc.
John Harold Wallace Turner, B.Sc.
John Letham White, C.B.E., D.L., B.Sc. (*Edinburgh & East of Scotland*).
George Ambler Wilson, M.Eng.
Robert Meredydd Wynne-Edwards, D.S.O., O.B.E., M.C., M.A.

And four Past-Presidents to be elected in November 1954.

Mr J. W. Moncur moved that thanks be accorded to the Scrutineers and that the ballot papers be destroyed.

The resolution was seconded by **Mr N. G. M. Anderson** and carried.

Mr D. A. Brown, acknowledging the resolution on behalf of the Scrutineers, said that this year they had felt themselves to be members of a rather exclusive club, with only seven other members. The work had gone very smoothly. Although civil engineers often disclaimed an ability to understand mathematics, they would probably be interested in some figures. This year 9,523 papers were sent out and 1,867 returned.

Considered as a percentage of the corporate membership, that was 73 per cent and 14·3 per cent. There were 69 invalid papers, which was more than double the number of the previous year.

Mr R. Weir moved that Mr J. A. Johnston, Member, be re-appointed Honorary Auditor for the current financial year; and that Sir Alan Rae Smith be re-appointed the professional auditor for the current financial year.

Mr P. O. Wolf seconded the motion, which was carried unanimously.

Mr W. Fillingham-Brown moved that the thanks of the meeting be accorded to the President for his conduct of the business as Chairman of the meeting.

Mr H. D. Manning seconded the motion, which was carried with acclamation.

The meeting then terminated.

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